Knowledge elicitation support for virtual multi-expertise teams

This thesis investigates new methods to capture individual knowledge crucial to the co-construction of team knowledge needed for excellent team performance.
Based on results of prior research and consultation of experts from industry and academia new knowledge support have been developed to enhance knowledge development in computer mediated teamwork The ACE method developed and tested in this thesis supports a team's expansive inquiry to find new solutions to complex problems. Expert based suggestions and enabling functions dynamically supports the growing team knowledge of multi-expertise teams exploring solutions to ill-defined complex problems.
With the emergence computer based professional teamwork in globally dispersed teams, successful methods enabling effective integration of relevant insights in the process towards the collective results is needed. Since the individual team member's knowledge and learning capacity are decisive for the ultimate quality of collective performance.

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Πάντα ῥεῖ καὶ οὐδὲν μένει

Herakleitos van Ephesos, 535 – 475 BC

Aan mijn ouders

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Contents

CHAPTER 1 – Introduction into knowledge elicitation support for learning and performance improvement in multidisciplinary teams

"Through learning we extend our capacity to create."
P. M. Senge, *The fifth discipline.* (1990, p. 14)

Introduction

The capacity to learn has always been important for individuals and groups. But today the awareness of its prominent importance has come to the fore. With the rapid pace of technological change in the interconnected economies of the world learning proves to be pivotal to the continuity of enterprises and the ongoing creation of economic wealth. With the growing knowledge intensity and interconnected nature of advanced professional work continuous learning on the job is obligatory to meet performance requirements (Argyris, 1993a; Castells, 1996; Davenport & Prusak, 1998; Nonaka & Takeuchi, 1995; Quinn, 1992). The necessity to share information, communicate relevant knowledge and co-construct collective solutions is obvious in for example concurrent new product development in global teams (Favela & Peña-Mora, 2001; Fulk & DeSanctis, 1995) and partly outsourced business processes (Lee, 2002; Quinn, 1999).

These developments fuel the scientific fascination with collaborative knowledge building processes in organizational contexts. In particular productive knowledge processes at work and emergent practices of multidisciplinary collaboration in distributed teams pose new research and design questions. Facilitation of intelligent use of available knowledge and creation of new knowledge receives vast attention. Yet many questions still have to be resolved. New research communities around issues of organizational learning, knowledge management, computer supported collaborative work (CSCW) and computer supported collaborative learning (CSCL) have emerged in the learning realm, aside of existing educational research (Allee, 1997; Brandon & Hollingshead, 1999; Brown & Duguid, 1991; Koschmann, Hall, & Miyake, 2002). Studies from organizational and economic perspectives at macro and micro level prevail over studies at meso-level, and those

using cognitive psychological and learning perspectives (Brandon & Hollingshead, 1999; Spender, 1996).
Questions regarding effective methods to stimulate learning processes in these contexts are very relevant. Especially, those investigating the possibilities to optimize individual learning processes in collaborative work settings.

Focus on knowledge elicitation

This thesis will focus on methods to support knowledge elicitation and communication for collaborative knowledge construction. First, for the very reason that dealing with complex problems is at the core of professional work. Second, because integration of individual insights, especially those participants hold implicitly, is so important for the process of knowledge development and team performance (Baumard, 1999; Boisot, 1995; Nonaka & Takeuchi, 1995; Nonaka & Konno, 1998; Reber, 1993; Stacey, 1998). The main research question is whether we can enhance knowledge articulation and communication via the introduction of specific activators and particular enabling structures. And if so, what is the impact of these stimuli on the collective team result and the flow of knowledge co-construction processes?
The importance of these questions seems evident, since the learning capability is so crucial for today's workplace performance. Knowledge is even assumed to be pivotal to economic sustainability and growth (Drucker, 1999; Kogut & Zander, 1992; Tuomi, 1999). Or as Kessels & van der Werff (2002,) define it: "the company's capability of being knowledge productive is the only sustainable economic asset" (p. 25).
Typical for professional work is that problems are complex, ill defined and sometimes even wicked. They vary from design of technological advanced commercial products or services (Bragge, Marttiin & Tuunanen, 2005) to policy proposals addressing complex societal issues (Bekkers & Lips, 2001). In collaboration with their teammates professionals have to tackle these problems. They need to achieve the best possible solution on time, smartly using relevant insights of individual team members.

It is well known that, especially in computer-mediated teamwork, there is a substantial risk of sub-optimal use of valuable individual insights due to the fact that these are either not yet articulated or not effectively communicated. Therefore this thesis focuses in particular on the question how to augment a person's capability to articulate, learn and communicate his/her ideas optimally for the co-construction of knowledge for the aforementioned type of teamwork (Brown & Duguid, 1991; Kessels 2001; Lave & Wenger, 1991; Lekanne Deprez, 2003; Weggeman, 1997).

Educational design challenges: future learning arrangements

Learning at work is an inseparable part of professional practice. Considering the paramount importance of effective articulation and communication of a person's own ideas in virtual teamwork settings, students should be introduced to new professional practices and advanced knowledge communication methods, prior to their professional career. We propose to do so via authentic work based learning in university education. (Jochems & Gerrissen, 2000; Westera, Sloep & Gerrissen, 2000). To train professionals at work or students during their preparation for work practices requires design of other learning modes, than the ones we are used to. New professional work practices often comprise learning-by-doing and collaborative knowledge construction processes embedded in performance driven team activities. Productive knowledge development at work often has to address at the same time individual, team and organizational aspects. In professional practice, learning moments are less predictable and less controllable as in conventional education. Coaching of learning while working requires design of dedicated learning interventions suited to the specific constraints of the workplace. Predefined learning modules and course programs conflict with the unpredictable, just-in-time and expansive learning requirements of today's workplace. Research in educational sciences has provided us already with a wide spectrum of well-founded suitable learning arrangements for competency development in conventional, predefinable, educational settings. Various excellent models, like the 4C/ID model of Van Merriënboer

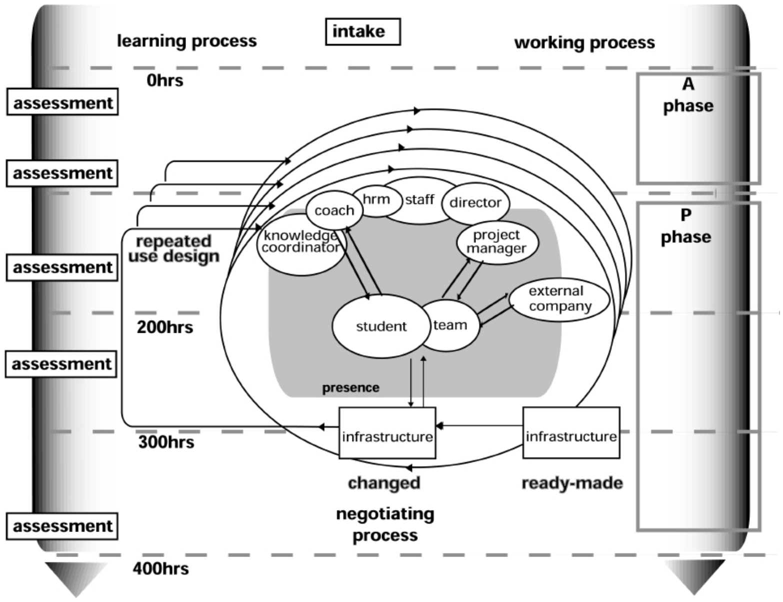
(1997) offer theoretical well grounded guidelines and instruments for regular educational settings, in which key conditions can be controlled. Now similar challenges lie ahead to configure new learning methods to support professionals for their intellectual teamwork (Engeström, 2001; Wierdsma, 1999).

Another challenge is the development of adequate learning scenarios to optimally prepare graduates for productive collaborative knowledge construction in their future professions.

Some new learning environments in particular address these learning needs. An outstanding example is the Virtual Business Learning model, (VBL), developed at the Open University of the Netherlands (OUNL).
In its, virtual business "enterprise-based learn-work" concept participants, either graduate students, professionals or both, are offered expansive opportunities for personal competency growth and collective performance, via complete immersion in a virtual business-learning environment (Bitter-Rijpkema, Sloep, & Jansen, 2003; Westera et al., 2000).
The VBL model uses immersion in "real business life" to familiarize student with advanced work practices. It helps them to develop and train the integrated knowledge building and team capabilities together with organizational feeling necessary for their professional careers.

Students work as employees in the virtual firm OTO (a systems design consultancy firm) or the VMAB consultancy firm (a firm focused on sustainability issues) in teams on real professional projects.
Learning is part of their ongoing work (Figure 1.1: A-phase, acquisition phase, P-phase, performance phase). It is supported via dedicated learning interventions and specific functionalities embedded ("ready-made" action cues) in the user's work environment (Bitter-Rijpkema & Crutzen, 2002; Crutzen, 2000).

Figure 1.1 Example of a learn work infrastructure: OTO's "Virtual Business Learning" environment



Source: Bitter-Rijpkema & Crutzen (2002)

Enhancing knowledge elicitation in professional practice

Living in a society where the creation of wealth is strongly knowledge driven, a person's learning and knowing capabilities are more and more perceived as a resource for "public" use (De Wilde, 2001). Momentarily there exists a strong impetus to investigate methods to stimulate "knowledge productive" learning processes aimed at performance improvement (Kessels & van der Werff, 2002). Dependent on background and purpose knowledge building stimuli address particular dimensions. At macro level management guidelines are defined (Allee, 1997; Kessels, 2001; Saint-Onge, 1996; Senge, 1990; Sveiby, 2001; Von Krogh, Ichijo, & Nonaka, 2000) to change external conditions at organizational and team level. Several researchers suggest creating social attractive settings fostering commitment and trust, while others propose to influence the team composition. Yet others suggest that active facilitation of the teamwork itself is the primary issue. The latter is the aspect we focus on in this thesis.

Prior research on elicitation support

Problems with not well-articulated or effectively communicated knowledge are not limited to team- or work practices. Educationalists investigate already for decades how prompting for explicit articulation might help early detection of misunderstanding and guide effective tutoring (Chi, 1997; Plötzner & Fehse, 1998; Van Lehn, Jones & Chi, 1992). Developers of expert systems explore multiple elicitation methods to reveal expert knowledge (Schreiber, Akkermans, Anjewierden et al., 2000). Prior research on effective knowledge articulation methods for teamwork focus on a variety of methods to trigger individuals to express themselves more clearly via shared formalisms. Existing ideas vary from various domain specific formalisms, to generic representational formalisms and heuristics for problem solving.

In the community of system designers methods have been developed to articulate in particular the design rationale (Burge & Brown, 2000; Lee, & Lai, 1991; Selvin, Buckingham Shum & Sierhuis, 2001a). In industrial and software engineering dedicated methods to structure design dialogues are developed (Burge & Brown, 2000; Klein, 2000). Specific representation and reflection prompts have been invented for group decision support (De Vreede, 1995). And finally the potential of visual elicitation formalisms, like concept maps, argumentation schemes and decision trees, is explored (Novak, 1998; Suthers, 1999; Van Bruggen, Boshuizen & Kirschner, 2003).

Overall a variety of valuable instruments have been developed and tested. Prior research on CSCW and CSCL has focused primarily on scaffolding, content structuring, technology mediation of communication, plus role facilitation and coordination (Gott & Lesgold, 1995; Koschmann, Hall & Miyake, 2002). Some studies specifically tested articulation in collaborative settings (Chi, De Leeuw, Chiu & LaVancher, 1994; Hall, Gott, & Pokorny, 1995; Plötzner, Dillenbourg, Preier & Traum, 1999; Selvin, Buckingham Shum & Sierhuis, 2001a).

Prompts to enhance strategic questioning and reflective thinking (King, 1992) as well as representational aids to surface underlying arguments and evidence (Carr, 2002; Cho & Jonassen, 2002; Van Bruggen et al., 2003; Suthers, 1999) have been tested. Social and contextual aspects of knowledge development in team settings received little attention until recently (Kreijns, Kirschner & Jochems, 2003). In well-defined educational settings positive effects of explicit stimulation have been reported. However studies thus far haven't yet disclosed precise conditions for optimal prompting of working professionals.

The actual use of existing elicitation methods in work practices lags behind expectations. First, the instruments often require a substantial learning investment to get familiar with the formalism and supporting tools (Selvin, Buckingham Shum, Sierhuis et al., 2001b). Secondly, professionals perceive the prescribed strict articulation formalisms as interfering with their natural way of doing, because these require extra effort. Consequently formal methods and tools are almost only used in settings where the nature of work and the value of standardized and formalized information exchange generate a discernable return on learning investment plus additional investment in effort and time.

Further empirical evidence has yet to be gathered to find out how articulation in professional workplace settings is best stimulated. Attention is particularly needed to study situations where team knowledge is critical to performance problems (Conklin, 2003).
In this thesis we address the question how to facilitate collaborative professional knowledge work in distributed settings adequately (Schön, 1983; Schön, 1987; Senge, 1990). More in specific we ask ourselves: given a certain task, team and context composition, how can we improve the process of collaborative knowledge construction and improve the desired outcome? What are the effects of elicitation prompting? How does it affect the quality of collective performance, and the knowledge building processes?

We specifically propose to concentrate on support for elicitation of individual insights. The underlying rationale for this choice is the importance of yet unarticulated individual knowledge for collective team result (Feltovich, Ford & Hoffman, 1997a; Polanyi, 1967; Reber, 1993; Scardamalia & Bereiter, 1996; Snowden, 2002; Von Krogh, et al., 2000). Surfacing all relevant insights available in team or organization is necessary to prevent performance problems, hampering processes, recursive dialogues or reinvention of the wheel.

Different perspectives on collaborative learning and knowing

Learning and knowledge are delicate concepts. For centuries they are topic of fundamental epistemological debate. The same terms have different meanings with different authors in different settings. Confusing is the interchangeable use of for example the concepts learning, knowing, knowledge and information. These concepts are often used with all their ambiguity. With a metaphorical reference, it is implicitly assumed that the specifics of the concept follow automatically without further explication. On the other hand, more precise definitions rapidly involve rather “thorny” fundamental epistemological issues, as Tuomi (1999) notices. It is not the objective of this study to explicitly address these “thorny” issues. To position the research presented in this thesis we present a few preliminary remarks to enable appropriate interpretation of its findings. In the context of elicitation for collaborative knowledge building we describe how the research presented in chapters 2 to 5 relates to the cognitivist and social constructionist perspective on collaborative knowledge building and the tacit-explicit dichotomy.

Cognitivists refer to knowledge as entities and objects, which can be separated from their owners. Knowledge consists of mental representations in an individual’s mind and in external representations. Once externalized and codified the representations can be processed as information. These knowledge objects can be shared, embedded in ontologies, knowledge repositories, and knowledge “management” or “expert” systems. Learning is this perspective is perceived as an acquisition process of pre-given universal true knowledge. In this tradition it is presumed that there exists a knowledge hierarchy. It starts with non-informative symbols i.e. data, and builds up via meaningful data i.e. information, to contextualized actionable information for personal use, i.e. knowledge. Learning is defined as a specific type of information processing. A person holds information in schemata and scripts, incessantly assimilating these to new information (Alter, 1998). The elicitation method, which inspired our *Ideasticker* tool at the start of the project, relates to this type of knowledge object and schema building assumptions. Triggers try to surface implicit mental schemata and scripts, using suitable expression formats that relate to these schemata or content structures.

The social constructivists view differs principally. Knowledge is not perceived as a property but a capability. Knowing and learning are supposed to emerge from social activity, processes of collaborative knowledge construction. Cognition is distributed, and learning emerges from social practice. Collective thinking patterns evolve from dialogues, from individual judgments and appreciation of different perspectives (Boland & Tenkasi, 1995; Lave & Wenger, 1991; Paavola, Lipponen & Hakkarainen, 2002; Stahl, 2000b; Vygotsky, 1978). Collaborative learning or knowledge building is primarily perceived as an iterative construction process. Knowledge development is a productive construction process in which ideas are generated, plans constructed and decisions for collective action taken (Cook & Brown, 1999; Fischer & Ostwald, 2002; Nonaka & Takeuchi, 1995; Paavola, et al., 2002; Scardamalia & Bereiter, 1996; Spender 1996). Learning emerges from ongoing processes of sensemaking, negotiated shared meaning and collective action. Abstractions and representations are means to develop this collective "knowing".

For the type of professional practices we investigate, "knowledge" is very much a matter of "knowing", the ability to interpret and act knowledgeable. Elicitation triggers in this frame of reference try to

enable optimal co-construction processes. Actions to trigger elicitation take often the shape of discourse and inquiry facilitators.
For the explication of individual ideas several terms are in use. We propose to use primarily the term elicitation. It stems from the Latin verb "elicitare", bringing to light. Thereby not only emphasizing the individual articulation act itself but also its further development.

Finally we have been inspired by the "evolving artifacts approach" (Ostwald, 1996). A framework developed by Ostwald and elaborated by Fischer (Fischer & Ostwald, 2002). Originally the framework has been developed for use with interactive systems designers. But with a broader definition of "artifacts" as the materialization not only of design code or objects but more in general as individual ideas, articulated in tangible "communicative" formats, it fits well to our field of study. It offers a sophisticated perspective on collaborative knowledge construction processes, apt to integrate both "knowledge as objects" and "knowledge as constructs". Inspired by this framework we think of ideas as conceptions that materialize in some format when they are elicited. Ideas become tangible in text, speech, schemata, narratives, etc. The materializations of articulated ideas can be viewed as " artifacts". These artifacts can be discussed, transformed and restructured. They continuously evolve during collaborative discourse and work. At certain points in time they crystallize into more stable structures. And in due time they become fluid again, when they are reconstructed for new purposes. The evolving artifacts frame enables us to capture the dynamics of collaborative knowledge construction. It offers a frame of reference in which there is space to recognize that professional knowledge development is a continuous social collaborative construction process, in which reified components play an important role. We think of these "objectified" concepts, as recognized knowledge constructs. Which in turn can be treated as "knowledge objects" in the knowledge building process.

Thesis overview

Chapter 2 of this thesis describes the results of a Delphi study we carried out to complement findings from an extensive literature review. The study focuses on critical factors for stimulation of productive knowledge construction processes in computer-mediated teamwork. The option of a Delphi study seems appropriate, since it offers an open format to elicit expert opinions and confront these with each other. It aims at collecting a solid qualitative basis for further investigation, incorporating both diverging and converging perspectives.

Chapter 3 describes the development of a new elicitation enhancer (the *Ideasticker*). This chapter offers insight into functions and design rationale of the *Ideasticker*. It further addresses the users' view on its potential and desired functioning. Special attention is given to the question whether delivery of elicitation support requires a one-size fits them all format or a tailorized format matching users' expertise backgrounds. Finally this chapter elicits the design principles used. It elucidates the design objective to develop minimal intrusive, easy to use support tools. This assumption results in the development of a kernel of elicitation functions, with different delivery modes to enable seamless integration into the team's workspace.

Chapter 4 reports the results of an "*Ideasticker*-in-use" experiment. Graduate social sciences students at the Open University of the Netherlands, team wise tested the new elicitation support. The test has a within-subject design to be able to observe how the same team experiences a situation with and without active support. Since our primary unit of observation is the team, this design is suitable for our purpose. In addition it offers us, given the limited number students, the best option to compare teams.

In *chapter 5* we review the first results of the final experiment. Based on new insights, reported in previous chapters, the articulation methods of the *Ideasticker* are extended to an improved elicitation support. The result is a scenario for augmentation of collaborative elicitation, referred to as the *ACE scenario*. Its focus is on maximal fit of elicitation support to the dynamic evolution of a teams' knowledge co-construction process. This is combined with triggers for expansive inquiry based on Argyris ideas of double loop learning and the applicable TRIZ methods for inventive problem solving. (Argyris, 1993b; Zlotin, Zusman, Kaplan et al., 1999).

Finally in *chapter 6* we draw up the balance and review critically the project's results. The following questions were leading for our retrospective reflections. What insight have we gained to enhance effective knowledge articulation and communication for distributed teamwork? Which effects did the elicitation support tested generate? How can we explain these effects? What are the practical implications of our findings so far? And finally which direction should future research take?

CHAPTER 2 – Supporting knowledge elicitation for learning in virtual teams[1]

Abstract

The growing complexity and dynamics of professional work increasingly require teamwork. Continuous learning while working will be obligatory to meet the performance requirements of the workplace. In this context asynchronous collaboration becomes more common and poses new educational design questions. Many questions regarding these new ways of working and learning are yet to be resolved. One pivotal issue is how to effectively support eliciting and sharing available but not yet articulated knowledge residing in the minds of individual team members. Suggestions derived from literature about knowledge elicitation point in different directions. In order to investigate knowledge elicitation support for professionals in virtual teams, an electronic Delphi study was executed. The objective was to gain insights regarding knowledge elicitation from a group of 16 representative experts. The results reveal the importance of customising multiple aspects to the specific situation. Each context requires a mixture of team, knowledge awareness and task related prompts. Based upon generic know-how with respect to enabling virtual team dynamics and community formation, social and task related knowledge prompts should be dedicated to the constraints and dynamics of the organisational context.

Introduction

The growing complexity and dynamics of professional work increasingly require knowledge intensive collaboration in teams. Work performance more and more becomes a knowledge- and collaboration-based activity. Solving problems, designing products and services require intensive communication of personal knowledge for the construction of collective solutions. Advances in Information and Communication Technology (ICT) enable distributed teamwork.

Continuous learning while working will be obligatory to meet the performance requirements of the workplace. Social and economic

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developments, such as the globalization of the economy and the shift towards the so-called information economy, put heavy pressure on education. On-the-job flexibility requires just-in-time application of necessary know-how from employees. Knowledge is seen as a competitive advantage. Virtual work environments become common as effective settings for knowledge sharing across business units (Nonaka & Takeuchi, 1995; Von Krogh et al., 2000).

Looking at traditional education, a change can be observed. The transfer value of education to work settings has been rather low. New alternative forms of education, like blended learning and cooperative education have to meet these new demands of the workplace. The integration of working and learning implies a return of education to real life settings. Many educators now consider both social context and social processes as an integral part of learning activities. Theories of constructivism and situated cognition suggest that for learning to be useful, the learner needs to be actively involved in constructing new knowledge within meaningful contexts, not merely absorbing it (Duffy, Lowyck & Jonassen, 1993). This is in line with competency-based education.

In both business and education similar developments can be observed. Learning and working in virtual teams increases in importance in both contexts (Bastiaens & Martens, 2000). The convergence of work, learning and the virtualization of teamwork require new educational frameworks (Westera et al., 2000). The aforementioned developments lead to new educational design questions on how to design and support collaborative learning and working.

An example of a new learn-work environment in which education and business merge, is the Virtual Business (VB) environment (Westera et al., 2000). Designed at the Open Universiteit Nederland, it offers a virtual learning framework for graduate students and an organizational learning environment for on-the-job learning of professionals. Learning in a VB team occurs in a virtual enterprise setting embedded into the professional's daily workspace. The VB environment primarily focuses on learning embedded in real work tasks and activities. Learning in a VB is team oriented, competency and problem based, embedded in an organizational context. It includes support of personal and collective competency growth. Concurrently, VB learning encourages explicitly a pro-active knowledge sharing and knowledge management attitude of its members.

The creation of shared knowledge is of crucial importance to the success of collaborative learning processes. Research into these processes uses multiple methods and perspectives from social sciences, psychology, organization sciences and human computer interaction. (Dillenbourg 1999; Kraut, Galegher & Egido 1988; Von Krogh, Ichijo, Nonaka, 2000). One of the major topics of interest is knowledge elicitation (Chi et al., 1994; Dillenbourg, 1999; Plötzner et al., 1999).

Construction of shared understanding and solutions requires more than simple exchange of explicit information. Elicitation of unarticulated ideas of participants lie at the basis of negotiated agreement upon common goals and collective solutions. This implicit knowledge is often referred to as tacit knowledge (Leonard & Sensiper, 1998; Polanyi 1967). There is no clear understanding regarding optimal prompting of elicitation and sharing of tacit knowledge. Researchers emphasize the fact that knowledge elicitation doesn't arise spontaneously (Chi, De Leeuw, Chiu & LaVancher, 1994). Ideas for stimulation range from elicitation via external knowledge representations, structured dialogues, argumentation elicitation and the use of artifacts for community formation. (Chi et al., 1994; Plötzner, Dillenbourg, Preier, & Traum, 1999; Stahl, 2000b). Many support tools are task-oriented. Some offer very dedicated support in close relation to the task at hand. Others offer more generic support for information exchange. Empirical studies (Kraut et al., 1988) indicate that social interaction probably is so critical to successful knowledge creation that neglecting this aspect will limit collaborative knowledge construction.

Thus it is pivotal to consider the design of optimal support for learning and task performance processes occurring in asynchronous communication of learners and professionals collaborating virtually (Bastiaens & Martens, 2000; Dillenbourg, 1999). This article focuses on the design of tools supporting elicitation of implicit knowledge in function of the construction of shared understanding. Commonly encountered is the view of embedding support tools in a single mode. These tools are either generic or very specific, dedicated to the common characteristic of a group. Existing literature, however, shows that several critical variables regarding the use of knowledge elicitation support have not yet been explored. One such variable is the need for flexibility of elicitation support. Aspects crucial for effective activation of elicitation of not yet articulated knowledge seem to be related to characteristics of individual team members and the context of learning and working. Experts and novices typically prefer different kinds of support. As a result of differences in individual learning and working habits, we wonder which dimensions need to be addressed for optimal support. To which extent do task variables, context variables, the individual's profile and team characteristics have to be triggered?

Expectations derived from the research literature point in different directions with respect to the nature of knowledge elicitation itself and the interdependence of critical factors influencing elicitation support of co-working professionals. Hence further exploration was needed to clarify this. Therefore we executed an electronic Delphi study to elicit the perceptions of a group of representative experts regarding knowledge elicitation processes and its support.

Delphi study: exploration of critical success factors for knowledge elicitation support

An electronic Delphi study – *ACE* Delphi - was chosen as an effective and efficient method to elicit insights into augmentation of knowledge elicitation. Delphi studies often have been used for forecasting and policy making (Linstone & Turoff, 1975; Kenis, 1995). We compared interview and survey research to the Delphi method. On the dimension of specificity and subjectivity, all these methods are strong fitting neatly to a particular research question. The choice of the Delphi method was based on the following advantages. The Delphi method (Kenis, 1995; Linstone & Turoff, 1975) offered us the possibility to address a group of experts more efficiently than via interviews or surveys. In Delphi sessions experts are able to amend and act in response to all ideas posted by their peers. Consequently each expert has the opportunity to take all factors brought forward into account and integrate them into their final judgment. Due to sequencing and pre-structuring needed for interviews and questionnaires relevant insights could be missed, while these insights are easily expressed in the open format of a Delphi study. Apart from its strength on eliciting all kinds of important information, a Delphi also allows the study to fit easily into the work habits, time pressure and agenda constraints of the expert population.

We divided our Delphi study in two sessions. The first session centered on critical success factors for elicitation support of collaborative teamwork in virtual learn-work environments. The leading question was what experts consider decisive for knowledge elicitation support. In the second session we focused our attention on the required functionality and customization of knowledge elicitation enablers. In this session we tried to identify which methods of prompting show potential.

Method

Our type of Delphi study, sometimes referred to as Group Delphi (Kenis, 1995; Webler, Levine, Rakel & Renn, 1991), can be described as a technique aiming at obtaining the most reliable converging or contrasting expert opinions. Experts are questioned, in consecutive debate sessions. Feedback from former sessions is mirrored until a stable state of opinions is reached. Typical for the *ACE* Delphi study was a heterogeneous response group. Experts reacted under their own name. The Delphi was in Dutch. The electronic Delphi study took place asynchronously during a 4-week period. There was no face-to-face interaction. Each participant had time for thought and equal opportunity to contribute. The experts' opinions were elicited in two debate sessions wherein experts could change and specify their opinion. Feedback to the group presented individual and collective views. Conclusions were reached taking each other's contributions into account.

Participants

Special care has been given to the selection of group members. We pursued a broad range of expertise since the objective was to explore the variety of views. Experts were selected from the national community based on their reputation, either derived from their publications or their professional track record. Special attention was given to find representative experts of equal importance in the professional community. Of the sixteen Dutch experts participating in this study, nine had a scientific background as researcher or designer in higher education, seven participants were practitioners working as staff member or executive in commercial enterprises.

Procedure

The Delphi study started with an introduction into the electronic environment, a survey of the expert's background and personal statements with respect to collaborative knowledge elicitation. The first session focused on generic critical success factors for collaborative knowledge elicitation in asynchronous distributed working teams. Special attention was given to three dimensions of knowledge elicitation, namely elicitation in function of personal competency growth (column A in Table 2.1), organizational knowledge productivity (column B in Table 1) and co-construction of shared understanding, or collective memory (column C in Table 2.1).

The second session focused on specific needs and functionalities of knowledge elicitation support. Special attention was given to instrumentation of knowledge elicitation prompts (column D in Table 2.1) and aspects to study (column E in Table 2.1).

In both sessions facilitation was low profile, restricted to the process, keeping the debate open enough to enable new perspectives to be shared. After each session the facilitator provided a synopsis. The participants commented and agreed with the synopsis as an adequate representation of the debate. Participants expressed their personal perspectives on issues brought forward via electronic forms indicating their perception of importance and consent with the statements as posed. Afterwards the results were aggregated in a concluding report.

Analysis

The Delphi method is both appreciated and criticized for the richness of qualitative insights it generates. Thereby leaving the researcher with the challenge to adequately structure and evaluate the data. The latter was achieved by identifying semantic expressions, defined as discernible expressions of a participant's thoughts. Three reviewers categorized them into a matrix in which rows depict the main issues raised by the participants and columns A to E, described previously, depict the issues raised as input for both the Delphi sessions. Results are presented in Table 2.1.

Table 2.1 Matrix ACE Delphi study with numbers of expressions

		Focus 1st Delphi session Generic critical success factors			*Focus 2nd Delphi session Instrumentation and research*	
	Issues raised by the participants	A: Persona competency l	B: Organizational knowledge productivity	C: Creation of collective memory	D: Support tools needed	E: Aspects to study
1	Knowledge attitude (productive and constructive)	2	6	2	8	3
2	*Learning attitude (active and participative)*	*6*	*1*	*2*	*1*	*0*
3	Knowledge awareness (knowledge resources, conversations, reflections)	0	6	1	10	0
4	Coordination of knowledge processes (speed to put knowledge into action)	0	1	0	0	0
5	Articulated meaning (definition of variables)	3	4	2	2	3
6	Context affordances and dependency (virtual, team setting)	3	8	1	6	1
7	Team awareness and dynamics (composition, trust, culture)	0	10	1	1	0
8	Community formation and continuation	0	0	0	7	1
9	Motivation factor (challenge, fun)	1	3	0	0	0
10	Added value (compared to default situation, to alternatives)	2	2	1	1	1
11	Articulation of shared goals	0	6	0	0	1
12	Supportive instrumentation (content, process related), metastrategy support (coordination, representation of ideas, communication of meaning)	5	3	0	5	1
13	Balance (mixture of interdependent factors)	2	7	1	5	1
				Total number of semantic expressions N=142		

Note: Focus 1st Delphi session: critical success factors for collaborative knowledge elicitation
Focus 2nd Delphi session: instrumentation and research for knowledge elicitation support

Results

In Table 2.1, a total of 142 semantic expressions are discerned, 84 of them occurred in the first debate and 58 in the second debate. Statements in the first debate cluster primarily around team awareness and team dynamics for organizational knowledge productivity (cell B7). Experts stress the importance of complementary assets (like personal characteristics and knowledge) of individual team members as a basis for trust, shared conventions and shared ambitions within the team (cell B3). A productive knowledge attitude of team members (cell B1, A1, C1) and knowledge awareness stimuli in the virtual team environment (cell B1, A1, C1) are perceived as especially important aspects of distributed teamwork.

Recruiting personnel with a knowledge productive attitude is one way of accommodating, facilitating this attitude another (cell D1). Affording productive knowledge creation in teams is perceived as a quite complex process. It requires a mixture of facilitation, concurrently addressing multiple dimensions of collaboration and knowledge interaction (cell B13, A13, C13, D13). Experts mentioned the significance of a challenging environment in which creative unrest is combined with basic stability. This in turn requires articulation and coordination of team expectations and conventions (cells B11, A12, B12, D12).

In general, the experts state that knowledge elicitation prompting only will sort lasting effects if the particularity of the context is taken into account and explicitly reflected in the design of elicitation support, (cell B6, A6, D6). There was relatively little attention for generic instrumentation. Experts rather looked for meta-strategies to develop customizable support (cell D12).

The experts converged as to the importance of clear and explicit articulation of the added value of the team setting (cell B10, A10). Opinions diverged with respect to the question in how far knowledge processes within a virtual team differ from face-to-face settings.

Analyzing the clustering of expressions in column B, it appears that experts are aware of the significance of the organizational aspects of learning. Learning for individual competency growth is discerned as relevant for knowledge elicitation support though learning related to knowledge productivity received more attention. Expressions explicitly addressing knowledge elicitation processes in function of the creation of a collective memory however attracted less distinct attention. Experts perceived it as subcategory belonging to the wider context of teamwork. Several cells, (B5, B11, A5, C5, D 5) show the importance of explicit articulation of shared goals and explication of meaning.

The results of the second session show a clustering of expert attention on support for knowledge awareness (cell D3) and affordances for a knowledge productive attitude (cell D1, E1). Once more the problem of contextuallity of team support and community formation was stressed (cell D6, D8).

Experts found facilitation of a knowledge constructive attitude of team members of the greatest importance. A team should be equipped with knowledge finding tools and a stimulating environment for community formation. These are assumed to trigger team members to constructively express their ideas in function of the problem solution process. Neither generic support with respect to representation of arguments and dialogue enhancers nor dedicated tools for the task at hand were perceived as factors of primary importance.

Discussion and conclusions

The current study provides insights into knowledge elicitation within virtual learn-work activities embedded in an organizational setting. Blending support to multiple aspects of a specific situation is needed. Interdependency of the variables influencing collaborative knowledge elicitation changes over time. Current research concentrates on task specific support of team members. The results of the Delphi study point towards the need for support of social and community related aspects of knowledge processes occurring in professional teamwork.

Clearly the qualitative character of a Delphi study has its limitations. Much is left to the expressiveness of the experts and the reviewers' skilful interpretation. Therefore, in the near future this study will be followed by experimental research in which we will try to manipulate key variables that resulted from this study. Results point to the importance of customizing multiple aspects to a specific situation. Each context requires a mixture of team and knowledge awareness and task related prompts. Based upon generic know-how with respect to enabling virtual team dynamics, and community formation, social and task related knowledge prompts should be designed dedicated to the constraints and dynamics of the organizational context. Knowledge elicitation has to be prompted during the lifecycle of a team or community accommodating to its evolution and changes over time, primarily focusing on knowledge awareness, stimulating knowledge constructive interactions.

CHAPTER 3 – Elicitation support requirements of multi expertise teams[1]

Abstract

Tools to support knowledge elicitation are more and more used in situations where employees or students collaborate using the computer. Studies indicate that there exist differences between experts and novices regarding their methods of work and reasoning. However, the commonly preferred approach tends to deal with team members as a single system with "common", shared preferences. The question is to what extent this approach is optimal. From literature potential difficulties with uniform knowledge elicitation support for workplace or workplace-alike settings of teamwork can be derived. We carried out two studies to investigate whether support tools for knowledge elicitation should explicitly take into account the expertness of team members.

In order to gather qualitative data concerning critical factors of effective knowledge elicitation support for professional teamwork a Delphi study with known experts has been conducted. The experts accentuate the significance of a context-fit of supportive action over content or functionality. In their opinion prompting must be tailored to the task at hand, team characteristics, team culture and context. In a second study we gathered qualitative insights into user-elicitation preferences, especially in relation to a user's proficiency in the field. Subjects of this study were graduate students studying for a profession as social worker. Respondents' elicitation preferences didn't correlate significantly with the expertness dimension. Further interpretation and comparison of the results from both studies seem to indicate that it is not so much the proficiency of the team members as well as the attunement with the surrounding context that is critical for the effect of elicitation support.

Introduction

More and more professional learning takes place in open learning environments, co-operating with peers. Computer-mediated forms of collaboration between distributed team members are becoming part of daily practice. Cases in professional practice and in computer supported learning show that effective knowledge communication in computer-

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mediated groups doesn't emerge automatically. Many problems with information and knowledge exchange during collaborative task execution are reported (Alpay, Giboin, & Dieng, 1998; Mulder, Swaak, & Kessels, 2002; Zack, 1998). Underperformance might occur when relevant knowledge of individual team members cannot be taken into account, since it isn't clearly articulated or understood (Allee, 1997; Buckingham Shum & Hammond, 1994).

High quality output of multidisciplinary teams within tight time constraints becomes of crucial importance in our society (Davenport & Prusak, 1998; Drucker, 1992; Kogut & Zander, 1992; Brown & Duguid, 1998). With the growing importance of virtual collaboration on knowledge intensive tasks both in professional and in educational practice, systematic investigation into enablers for effective knowledge articulation is needed (Brown & Duguid, 2000; Johnson & Johnson, 1994; Plötzner, Dillenbourg, Preier, & Traum, 1999; Conklin, Selvin, Buckingham Shum, & Sierhuis, 2001). The implicit knowledge of individuals is seen as crucial for the collective performance (Polanyi, 1967; Leonard & Sensiper, 1998; Nonaka & Takeuchi, 1995; Von Krogh, Ichijo, Nonaka, 2000; Boisot, 1998). So, within the collective quest for a shared solution in multi-disciplinary, multi-expertise teams it is relevant to focus on augmentation of adequate knowledge articulation and communication. Hence investigation into the first resource for team knowledge building is needed to understand processes that lie at the roots of emerging common ground and collective action in the team process (Beers, Boshuizen & Kirschner, 2003; Selvin, 1999).

Insight is needed to incite knowledge articulation by way of support scenarios, which augment collaborative elicitation. Before a well-founded scenario for augmentation of collaborative elicitation can be designed, more insight is needed regarding the impact of specific variables such as expertise level.

Current research regarding knowledge communication in teams concentrates on actions enabling the emergence of a common frame of understanding (Conklin et al., 2001; Mulder et al., 2002). Several elicitation methods are proposed to facilitate elicitation for collaborative work and learning (Selvin, 1999; Conklin et al., 2001). Many incentives propose an explicit structured expression of one's proposition in some structured format (Baker & Lund, 1997; Chi, Glaser, & Farr, 1988; Plötzner et al., 1999; Fischer & Mandl, 2001; Jonassen & Carr, 1999; Van Bruggen, Boshuizen, & Kirschner, 2003). Orientation, representation and modality of the elicitation prompts as well at their formats and structure vary. Multiple formalisms have been proposed to structure externalization of ideas (Bell, 1997; Kirschner, Buckingham Shum & Carr, 2003; Ostwald, 1995; Puntambekar & Kolodner, 1998). Some suggestions are content driven, and connect directly to the domain structure. Others propose scaffolding the learning process (Scardamalia & Bereiter, 1996) in a more generic way. Mulder for example proposed the insertion of a question mark to trigger further inquiry (Mulder et al., 2002). Yet other authors recommend prompting for argumentation structuration (Toulmin, Rieke & Janik, 1984): eliciting claims, underlying arguments plus evidence (Carr, 2002) or rationales (Ostwald, 1995). Positive effects of active elicitation have already been reported (Chi, et al., 1988; Jonassen & Carr, 1999; Plötzner et al., 1999; Jeong & Chi, 2000). Chi, et al. (1988) found positive results with triggers enhancing students to elicit self-explanations. Plötzner, et al. (1999) observed similar results when they stimulated peer-to-peer explanations. Fischer & Mandl (2001) investigated the use of cues and scripts and observed how supportive scripts intensified the collaborative knowledge discourse.

Many structuring scaffolds are still text-based. Several researchers however propose structuring by way of graphical representations for cognitive reasons (Suthers, 1999; Sumner, Domingue, & Zdrahal, 1998; Van Bruggen et al., 2003). Graphical schemes are supposed to match better with the mental schemata of individual cognition then the linearity of text. Methods to enhance graphical representations are often used in the field of science, engineering, and business studies. In these domains practitioners are already accustomed to communicate via predefined formalisms, since unequivocally typifying a problem in both entities and relations is quite common there.

Studies of elicitation triggering report positive effects mostly in rather "closed", well-designed and defined learning environments with fairly homogeneous groups of students or experts (Plötzner et al., 1999). Most problem solving activities in natural settings however take place in very fluid open contexts with ill-structured problems. Because reported empirical findings in literature are often derived from well-defined experimental settings, a literature study alone doesn't provide sufficient insight into the decisive factors influencing the successful knowledge flow in collective task fulfillment. They don't explicitly focus on knowledge-building processes in real life multi-disciplinary multi-expertise teams. Hence it can be questioned whether the same positive effects will occur in these natural settings with ill-structured problems. Can the same support be applied? And what effects can be achieved for collaborating project members stemming from different domain backgrounds having miscellaneous levels of expertise? Insight into specific requirements for elicitation prompting in mixed virtual teams is still insufficient for the design of elicitation support for work-based learning of both professionals and students immersed in authentic work. The design of support for such complex processes as learning and knowledge development in real life settings requires capturing essential determinants from both academic research and professional practice.

Positive effects of elicitation prompting are reported for specific instantiations of collaborative learning and working. A common denominator of these studies seems to be that students or professionals work on a well-defined task (Scardamalia & Bereiter, 1996) within a rather homogeneous team setting. The question is whether reported positive effects of elicitation prompting will also occur with ill-structured problems in teams with heterogeneous expertise backgrounds and levels.

It is well known that individual's knowledge building processes differ according to a person's proficiency in the field. Knowing that problem-solving methods and knowledge building vary according to an individual's expertise, we assume that elicitation support of mixed groups might require a different approach than the "one-size fits them all" triggering approach used so far (Feltovich, Spiro, & Coulson, 1997b; Bromme & Nückles, 1998). We expect that supportive action for collaborative teamwork require different support modalities for individuals according to their expertness. After all, it is known that individual knowledge building processes differ according to a person's expertise in the field. At present there isn't much empirical evidence with respect to accommodation of support to personal expertness. According to findings on the differences in working habits and learning processes we assume there are different preferences regarding the type of support preferred, the nature of supportive action, timing of elicitation prompts and activation mode. Hypothetically we assume that novice-like users will prefer system activated declarative support, alongside task fulfillment. More proficient users will prefer rich, user-activated, strategic support (Choo, 1989; Chi et al., 1988; Feltovich, et al., 1997b).

This article presents two studies designed to gain more information about the impact of expertise level on the need for knowledge elicitation support. The first study is a Delphi study with experts on computer collaboration. The second study directly assesses students' needs for elicitation support. Aim is to reveal whether the differences between novices and experts are significant regarding the perceived needs for elicitation support. In this study we explore actual user perceptions guided by the hypothesis that: users with different expertise profiles require elicitation support adapted to their specific needs.

Study 1: Delphi study, investigating critical influences on knowledge elicitation

To gather a reliable overview of the expert's converging and diverging opinions we compared the format of a group Delphi (Kenis, 1995; Linstone & Turoff 1975; Webler, Levine, Rakel & Renn, 1991) with other possible formats such as surveying and interviewing. A Delphi study appears best suited. It's flexible and efficiently facilitates grasping the variety of qualitative insights from a representative expert population. Compared to close or open-ended surveys the full variety of ideas can be captured without the narrowing effect of predefined structures. Contrary to survey studies a Delphi is not prestructured. Participants can freely react on each other addressing earlier contributions. They also can change their opinion.

Questioning expert scientists and practitioners simultaneously in an open way offers the best opportunity to gather a rich variety of additional insights hold within the professional community regarding key variables for knowledge elicitation support in natural settings of educational and workplace teamwork. However, this unstructured and qualitative nature of a Delphi presents both advantages and risks as stressed in Linstone & Turoff 's (1975) standard work.
We paid special attention to guarantee the representativeness of the selected group in order to assure a dynamic mix of homo-and heterogeneity. Aloof process facilitation should guarantee a free flow of converging and diverging opinions in the debate, and subtle summarization should preserve the richness and variety of articulated opinions.

Participants

A representative group with respect to their expertise on knowledge communication and collaboration in teams of experts from academia and professional practice has been invited to this Delphi study. Experts with a solid reputation within the national professional community in the field of knowledge communication and collaboration in teams were selected. Professionals not only had diverse backgrounds, but also represented different streams of thought and professional experience.
Sixteen experts participated. Nine experts came from academia, holding positions such as researcher or instructional designer. The academics worked already for several years in senior research positions, as professor or assistant professor at Dutch universities where they are investigating, implementing or teaching in the domain of collaborative learning and work or knowledge management. The seven participating business professionals were experienced executives or senior consultants in renowned industrial enterprises or consulting firms. They all were involved in the exploration or use of innovative knowledge practices and teamwork in their firms. They came from differing backgrounds and worked in various fields ranging from education and training to engineering, telecommunication services and business consulting. Accordingly, they adhered to different perspectives

on virtual teamwork and learning. To ensure adequate time for the Delphi study the debate had to fit easily into the overloaded agenda's of the experts. Therefore we opted for a fully electronic Delphi study. To provide optimal flexibility we primarily used asynchronous communication.

Procedure

This Delphi study aimed at capturing relevant insights on influencing factors of effective knowledge communication during "real-world" team learning and teamwork. During a month, experts debated asynchronously. In a Delphi study statements are presented to initiate the discussion (Kenis, 1995; Linstone & Turoff, 1975). From then on experts are free to address relevant issues. Participants are continuously able to read and respond to the ideas of their peers, converging as well as diverging ideas and arguments.

The study consisted of two sessions. Statements derived from literature with some context information have been used to challenge experts to articulate their views. At the start, experts presented themselves and submitted a personal statement concerning the subject.

The first session focused on the examination of essential variables for effective knowledge articulation and communication in professional teamwork. The second session zoomed in on individual and context variables for the design and implementation of elicitation support. In this session experts discussed research and development requirements for successful knowledge elicitation enablers.

The facilitator opened both sessions and at the end of each session mirrored individual and collective views back to the group. During the debate facilitation was restricted to the process, enabling an open climate towards introduction of new perspectives. The debate went on till participants had had enough time to contribute and a stable state of opinions was reached. Taking all contributions into account, the facilitator provided a synopsis after each session. Participants amended this synopsis and expressed whether in their view the final conclusions drawn and the synopses were an adequate representation of the debate.

At the start of the first session the facilitator requested each participant to shortly introduce him/herself in relation to the theme of knowledge productivity in virtual teams. Likewise the facilitator asked participants to deliver opening statements. The facilitator triggered experts to make expressive statements by posing challenging statements regarding knowledge exchange in virtual teams at the start of each session. The problem that a "group has no head ", described by Fischer & Sugimoto (1999) was used for this purpose in the first session.

Thereupon team members willingly posted personal contributions. The first session focused on critical factors of knowledge articulation and productive knowledge sharing plus criteria for it's effective support. During the debate the facilitator only provided summarizations and process support. At the end of this session the facilitator wrote a synopsis, covering the debate, highlighting conclusions, supportive annotations and opposing amendments. Participants were asked to assess whether the synopsis of each session was a complete and adequate summation of the debate.

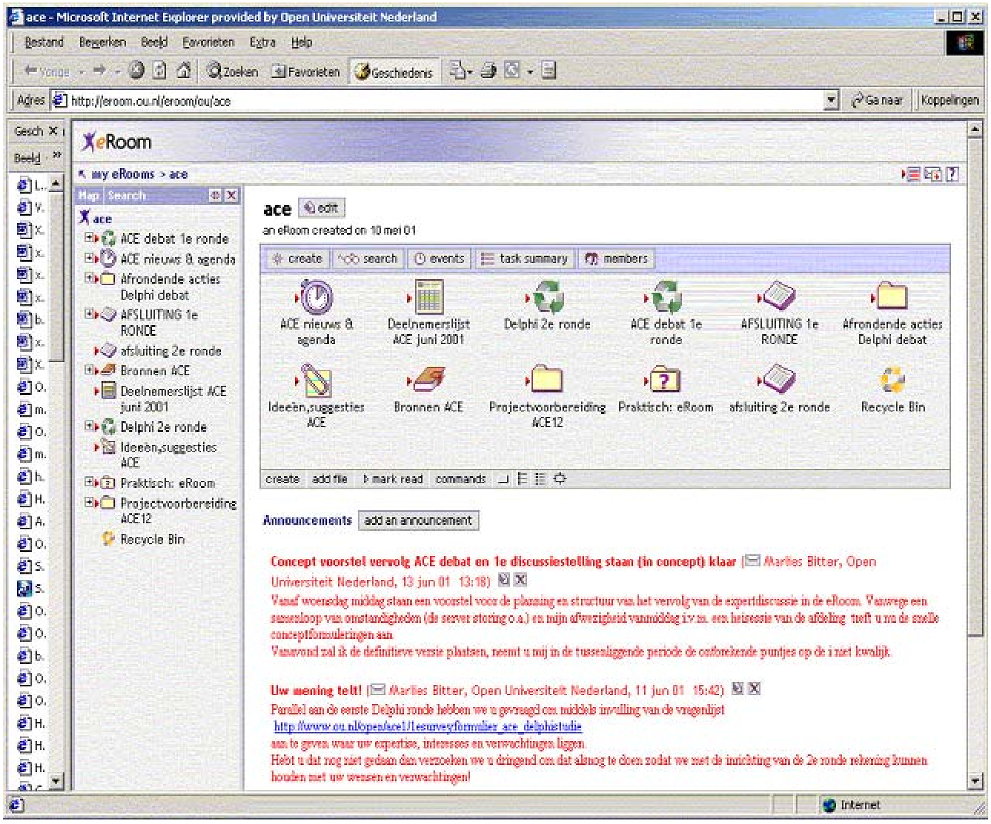
To ensure that subsequent summaries and reports accurately mirrored the fine distinctions and differentiations made by the participants, the facilitator was asked to explicitly check whether all articulated ideas and arguments were taken into account in the summaries and were adequately processed in the synopsis. A second person was asked to control for the adequacy of summarization, preventing selective reporting.

The second session was organized in the same electronic (eRoom®) format, following the same procedures. Now the debate focused on the functionality and development of a method for optimal elicitation support. At times when a variety of issues were addressed the facilitator offered participants an opportunity to rank issues addressed. Again the facilitator would summarize all relevant, converging and diverging ideas, into a synopsis and request approval. Finally both synopses have been combined into a concluding report.

Materials

Participants communicated with each other, in an easy to use virtual discussion space (eRoom®). A concise written introduction in the discussion facilities for this groupware environment was offered. This provided a sufficient basis and no additional training was needed.
Figure 3.1 provides an illustrative screenshot that gives a flavor of the content and representation format of the electronic discussion environment.

Figure 3.1 Screen of the Delphi eRoom ® environment[∞]



[∞] Acknowledgement: Mr. H. Spoelstra, mkm (OTEC) kindly offered us the possibility to use an eRoom® discussion space for the Delphi study.

Results

This Delphi study resulted in a rich collection of ideas embedded in large discussion threads. Logging saved all ideas and lines of argumentation. The key ideas and lines of argumentation were written down in the synopses and final report.

Opening statements almost automatically fuelled an exchange of ideas between team members, even without an explicit request to reflect and react on one's peer's judgments. The participants voluntarily posted a multitude of contributions. Recognizing the limitations of the Delphi method aloof process guidance aimed at no more than enabling effective articulation of the participant's opinions. The facilitator should only take care of the process control. To prevent implicit imposition of structure or ideas content remarks were forbidden to the facilitator apart from the prescribed statements in the opening scripts of each session.

In the first session, successive individual contributions basically consisted of elaboration and refinements of earlier claims and introduction of new contrasting ideas. The debate evolved from reflections emphasizing the importance of a person's knowledge and his/her competency to communicate information to a mixture of crucial contextual conditions enabling or hindering the emergence of shared understanding for optimal task fulfillment in a specific situation.

Contrasting views persevered, regarding the crucial role of individual knowledge competence on the one hand and the emergence of collective competencies under influence of favorable context factors on the other. Hence the experts' advices varied accordingly from methods to explicate and validate available knowledge, to tailored stimuli aimed at context variables like group building, shared vision, coordination and trust, thus enhancing relevant knowledge sharing activities required for the specific team task at hand.

In the second session the experts collectively supported the idea that a more practical approach is needed than the literature reflects, to further investigate and test viable knowledge elicitation enablers. The importance of finding metrics for the value added by these supports is widely shared. Yet contrasting views are held between business practitioners and academics regarding the specific requirements and type of the knowledge elicitation enablers needed. Academic experts are looking for dedicated, theoretically based, cognitively focused supports, while the business experts are more oriented towards pragmatic constructs.

Three reviewers were asked to identify coherent semantic expressions in the logged discussions and classify them. The unit of analysis used was not the full statement of a participant, but a “semantic expression”. We define a semantic expression as a discernible expression of a participant's thought. In the few cases where reviewers initially differed in their unit of analysis, exchange of argumentation led to a shared discourse segmentation and labeling.

In sum, 150 semantic expressions are distinguished: 92 in the first debate and 58 in the second session. Reviewers independently categorized expressions with labels as mentioned in Table 3.1.

Table 3.1 Category labels used in the analysis of the Delphi study

Session	Number of expressions	Labels
1st Delphi session: success factors for knowledge elicitation.	24	Knowledge elicitation for personal competency growth.
	57	Organizational knowledge productivity.
	11	Co-construction of shared understanding.
2nd Delphi session: required research for knowledge elicitation tools.	46	Needs and functionalities of knowledge elicitation support.
	12	Instrumentation of knowledge elicitation prompts.

Notice in Table 3.1, the predominance of (57) expressions related to aspects of knowledge productivity within the organizational context. Expressions relating to elicitation of personal competency growth count up to much less (24 remarks), while the need for shared understanding (11 expressions) receives substantially less attention.

All contributions were classified around key issues, derived from literature and the debate itself. These key issues are depicted in Table 3.2.

Table 3.2 Underpinning of the classification of key issues

	Categories	Number of expressions^	Resource
1	Knowledge attitude (productive and constructive)	21	Delphi debate; Kessels, 1996; Leinonen et al., 2002; Mulder et al., 2002; Scardamalia & Bereiter, 1996.
2	Learning attitude (active and participative)	10	Delphi debate; Brown & Duguid, 2000; Scardamalia & Bereiter, 1996.
3	Knowledge awareness (knowledge resources, conversations, reflections)	17	Delphi debate; Kessels, 1996; Mulder et al., 2002; Plötzner et al., 1999.
4	Coordination of knowledge processes (speed to put knowledge into action)	1	Delphi debate; Buckingham Shum & Hammond, 1994; Selvin et al., 2000.
5	Articulated meaning	14	Delphi debate; Alpay et al., 1998; Fischer & Mandl, 2001; Jeong & Chi, 2000; Ostwald, 1995; Plötzner et al., 1999.
6	Context affordances, dependency (virtual setting)	19	Delphi debate; Conklin et al., 2001; Feltovich et al., 1997a; Scardamalia & Bereiter, 1996.
7	Team awareness, dynamics culture	12	Delphi debate; Mulder et al., 2002.
8	Community formation and continuation	8	Delphi debate; Scardamalia & Bereiter, 1996.
9	Motivation factor (challenge, fun)	4	Delphi debate.
10	Added value (compared to default situation, to alternatives)	7	Delphi debate; Leinonen et al., 2002.
11	Articulation of shared goals	7	Delphi debate; Toulmin et al., 1984; Feltovich et al., 1997a; Ostwald, 1995.
12	Supportive instrumentation meta-strategy support (process, coordination, representation, content)	14	Delphi debate; Fischer & Mandl, 2001; Puntambekar & Kolodner, 1998; Suthers, 1999.
13	Balance (mixture of interdependent factors)	16	Delphi debate; Puntambekar & Kolodner, 1998.

^ Number of expressions in 1st and 2nd session.

Accents within our Delphi group differ from the distribution in research on computer supported collaborative learning and working. Yet, from this Delphi study observations, no further conclusions can be drawn due to the small group involved, the open multifaceted nature of a Delphi debate, and the qualitative nature of the data.

Analysis of results regarding success factors for knowledge elicitation emphasized by the experts as summarized in Table 3.2 demonstrate the primary prominence this expert population gave to a pro-active, participative attitude to learn and share knowledge of team members. Notice the densely populated categories: knowledge productivity (cell 1, 21 expressions), proactive learning attitude (cell 2, 10 expressions) and knowledge awareness (cell 3, 17 expressions). These ideas are in line with Kessels (1996), promoting a knowledge productive and pro-active learning attitude of professionals. Remarkable are propositions of several experts to afford this through combined actions, derived from content analysis of cell 4, 7 to 11. Suggestions vary from the careful construction of teams, mixing functional expertise in the team with a homogeneous knowledge-sharing attitude. After all, persons lacking an active learning and knowledge-sharing attitude are structurally endangering shared task fulfillment. This expert community underlines the importance of an adequate team selection at the start, followed by gap analysis addressing know-how lacunas. Subsequently, a team ought to be kept adequately informed about existing knowledge of each team member (cell 7 and 11). Those who see the individual knowledge competence as decisive particularly accentuate this topic and promote the use of yellow pages like tools. Others perceive expertise inventory tools only relevant as part of the whole cluster of context variables for effective knowledge elicitation. Supportive tools should support essential information management within the group and trigger continuous formal and informal knowledge interactions (cell 12). Supportive action for elicitation should be offered in an attractive way (cell 9). Value added via supportive action should be obvious (cell 10, 11). Facilitating team processes and shared knowledge construction is promoted by defining shared objectives and value adding instruments, thus enabling an effective knowledge co-construction process (cell 12, 13). One-dimensional support, focusing solely on one specific aspect, either the visual representation of knowledge or coordination of requested actions, is perceived as too limited. Concerted supportive action for collective sensemaking, representing emerging viewpoints during the incremental evolution of shared knowledge, together with coordination are seen as crucial for success. The experts differ about the optimal mix for concerted supportive action. Experts from the business field focus on enablers for shared motivation in order to create and keep a shared ambition alive. Their idea about knowledge awareness has a broader scope, than experts from academia. The academics are searching for more sophisticated support of specific aspects of knowledge, like support for argumentation and exchange of the mental schemes the team members' hold. Both business experts and scientists agree on the need for concerted action. A concerted action with scaffolds for interaction, enablers to build knowledge awareness and trust, combined with structuration of articulation and coordination. Business and academic experts however differ in their opinion about tools fit for these purposes. The business practitioners check on added value in pragmatic terms. The academics primarily look for theoretical sound and dedicated solutions. Based on seemingly shared assumptions this results in contrasting views of the experts on instrumentation and value added trough specific support tools.

The Delphi study resulted in multiple suggestions regarding concerted action. Tensions have been observed between the academic communities striving for rather advanced, focused supportive tools, and business practitioners looking for pragmatic easy to combine and easy to integrate tools.

In the general discussion we will look into the consequences of the experts' suggestions for the development of scenarios to augment collaborative elicitation.

Study 2: a study into users' elicitation preferences

The second study investigated issues regarding user-specific requirements for knowledge elicitation support of team members with differing proficiency characteristics.

We hypothesize that team members would show different elicitation support desires and expectations according to their professional expertise profile. Hypothetically we expect proficient team members (the experts) in this study to prefer self-activation of support. In line with Chi et al (1988) users with an expert type profile are expected to perceive elicitation support as valuable when the decision, when and how to use it, is left to them, assuring that they can follow their own line of work. Teammates with a novice-like profile are assumed to have a different attitude towards argumentative elicitation support. Novices are expected to be less confident about the optimal problem-solving method and therefore more open for guidance. We anticipate that novices will appreciate and use system activated procedures and prescriptions made available right from the beginning. For both groups we expect that a positive collaboration attitude (measured via the collaboration appreciation scale) will result in higher scores on elicitation expectations.

A Toulmin-based (Toulmin, 1958) elicitation support was introduced as a method to structure and evaluate one's own and one's peer's argumentation. As proposed by Toulmin, team members articulate their proposals by eliciting their claims, underlying argumentation, and supportive evidence. We assumed that introduction of this special method for systematic elicitation of underlying arguments would be positively perceived as helpful for knowledge communication during problem solving.

Participants

The survey study took place in the summer of 2001. Subjects were 28 students taking a course in social judicial client support at the Rotterdam Ichtus College of Higher Education. Twenty-three students returned the questionnaire, which is considered a representative proportion (82%). The respondents were between 18-23 years of age, three male and twenty female.
Heterogeneous student groups are typical for this curriculum for social work. Students in this group had diverse practice and study backgrounds. Their prior education was primarily on high school level or vocational training. Some students subscribe to these courses as a specialization in the final phase of their initial training, while others return to school after having worked as practitioners.

Procedure

The survey study took place in a social science methods course. Distinctive of this course is the fact that students had to collaboratively solve representative problems from professional practice. As part of this course students were required to design a collective intervention plan to address school absenteeism in a metropolitan city. Students should propose their solution to the problem, discuss intervention options and negotiate a collective intervention proposal. To facilitate the articulation and argumentation process students were offered a Toulmin based method of argumentation. Prior to task execution, participants were introduced to the Toulmin's model and it's potential to elicit arguments (Toulmin et al., 1984). They were invited to use Toulmin categories and were told how to integrate them in their text messages. No predefined tools were offered. The objective of this survey was to address perceptions regarding requirements of advantageous knowledge elicitation support for our target group: graduating students and working professionals.
We asked students to fill in a questionnaire about their working habits, support preferences, their experiences with structuring knowledge exchange during collaborative task fulfillment and the necessary modalities of support tools. Filling out the questionnaire took about one hour.

Materials

In order to investigate whether the degree of expertness makes any difference for support requirements we defined an expertness scale. For this purpose we relied on primary indicators of professional proficiency combined with self and peer perception of a person's expertness. We defined experts in this context as proficient professionals. The expertness scale addressed: educational background, self perception of the respondent as either a novice or expert, perceived peer perceptions of the participant, a self-reliant proficient, expert-like work habit, plus experience within the domain. As proficient professionals ("experts") are considered those who score as an expert on the dimension:

educational background (vocational), self perception (expert), and on at least two of the other dimensions (work habit, domain expertise, peer perception). All others were classified as novices. As a result within this group of 23 respondents 9 participants were characterized as "novices" and 14 as "experts".

In most cases, multiple items were constructed to increase the reliability and validity of the aspects measured. Items that have been combined into scales.

Scales were accepted as reliable if Cronbach alpha was higher than .60. We primarily used scales, represented in Table 3.3, to investigate relevant dimensions for enabling knowledge articulation. Complementary questions addressed respondent's specific ideas regarding support functionality (see Appendix 3.1 for a selection of representative questions).

The Toulmin appreciation scale measures positive attitudes towards argumentation elicitation. The collaboration appreciation scale investigates the respondent's positive attitudes towards collaboration. The argumentative elicitation scale measures the respondents' positive attitude towards bringing to the surface underlying arguments in function of the task. The collaboration expectation scale measures positive expectations of collaboration with respect to the collective solution to be reached, it's quality and the process.

Finally, we used a perceived usefulness scale, measuring the usefulness perception of elicitation support as perceived by the respondents. Apart from this we questioned users' elicitation activation preferences and preferred support functionality regarding the type of support, it's activation and textual or graphical articulation modalities.

Table 3.3 Scales used in study 2

Scales used in study 2	Number of items^	Cronbach Alpha
Toulmin appreciation scale	3	.94
Collaboration appreciation scale	6	.70
Argumentative elicitation expectation scale	5	.90
Collaboration expectation scale	3	.79
Perceived usefulness scale	2	.96

^All items were 5-point Likert scales.

Explorative data analysis, comparison of means, t-tests (with a significance level of $p < .05$) and MANOVA, were used to investigate differences in opinions between proficient "expert" users and "novices". Where appropriate, we checked for the meaning of outliers.

Results

As stated in our hypothesis, we assumed our respondents would differ regarding elicitation support needs according to their expertness. First we anticipated positive attitudes concerning collaboration and dialogue support. Indeed respondents expect some improvement of results from collaboration and explicit elicitation. We assumed that non-experts would show a more positive attitude than experts, since vital gains for their performance are at stake. However no differences of this kind were observed in this study.

As can be deduced from the results of this study, reported in Table 3.4, the scores for appreciation, expectation and perceived usefulness of elicitation support of both novices and experts tend to be neutral or lower. With respect to respondent's expectations regarding effects of argumentation support, measured through the Toulmin appreciation scale and perceived usefulness scale, we predicted different attitudes of novices and experts. Novices, being most in need of supportive action, are assumed to demonstrate more positive expectations than experts.

Yet analysis didn't show significant scores for the differences between experts and novices on these scales. The group as a whole didn't demonstrate high expectations. Both experts and novices don't expect explicit positive effects of the Toulmin method for systematic argumentation elicitation. Moreover no significant (p-value is 0.07) differences have been observed. Appendix 3.1 shows differences between novices and experts for specific questions. Novices more often hold either positive or negative opinions about Toulmin based support, resulting in high standard deviations. Appreciation of the experts is lower than novices. We wonder whether these results represent a stable opinion of our subjects; or that the specific value of Toulmin's method wasn't fully understood by the respondents. The usefulness perception of electronic elicitation support proves to be independent of its use to gain insight into one's own arguments or for the surfacing of your peers' arguments. Yet it is interesting to note that respondents emphasized the importance of knowing the arguments of their teammates, as a precondition for a further exchange of propositions.

Table 3.4 Results of study 2

	Expertness	N	Mean	SD	*p*-value	Mean	SD^
Toulmin appreciation	expert novice	12 8	.41 1.41	0.97 1.20	0.07	0.81	1.15
Collaboration appreciation	expert novice	14 9	2.21 2.13	0.67 0.52	0.75	2.18	0.59
Argumentative elicitation expectation.	expert novice	12 8	1.47 1.60	1.08 1.07	0.79	1.52	1.05
Collaboration expectation	expert novice	14 9	1.26 1.44	0.65 0.44	0.43	1.33	0.57
Perceived usefulness	expert novice	12 8	1.16 1.31	1.01 1.04	0.81	1.22	1.26

Note: *SD^* is from complete sample

Based on literature we assumed (Chi et al., 1988) that experts would follow their own line of work while novices would use the procedures and prescriptions available. Nevertheless responses of the students with

respect to their preferred work style didn't differ significantly. The non-significant differences observed are in line with the hypothesized trend: novices indeed tend to work more according to proposed procedures.
Furthermore we expected that preferences for elicitation support would vary in relation to the proficiency level of the individual; experts preferring self-activation and novices preferring system activated guidance. We also took into account that preferences might even differ within a person. The same person might prefer different supportive actions within his domain of expertise than outside his field. In our study, the majority of respondents show a preference for self-activation both in domains they are acquainted with and in domains they are unfamiliar with. The differences in preferences between experts and novices however are small and not significant. As to the modality of support an overwhelming consensus exists for the textual mode. With respect to visualization, the preferences varied across our population of respondents. Experts show more variation in their responses than novices.

General discussion

The investigations in this article explored whether elicitation support of multidisciplinary teams specifically needs to be adapted to members' expertness. On the whole, supportive actions for computer supportive collaborative learning and working tend to deal with team members as a single system having the same shared preferences. The design of optimal elicitation support for open and dynamic workplace learning practices, emerging both on the job and in initial academic education, requires further insight into the conditions of effective facilitation of knowledge communication.

In literature (Chi et al., 1988; Fischer & Mandl, 2001; Jeong & Chi 2000; Jonassen & Carr, 1999; Plötzner et al., 1999) differences between experts and novices are reported, regarding distinguishing patterns of reasoning and problem solving. Consequently we hypothesized that users with differing proficiency profiles would require distinctive elicitation support, adapted to their specific needs.

Two studies were conducted. The first study was intended to further investigate critical dimensions for elicitation support of multidisciplinary mixed expertise groups. This study tried to answer the question whether or not a representative group of experts from academia and business perceived the same key dimensions for elicitation support as retrieved from the literature or contributed additional insights. The second study attempted to answer the question whether or not dealing with supportive action for elicitation should address team members as a single ecosystem or should explicitly cope with structural differences in proficiency.

The first study produced rich perspectives on criteria for successful elicitation support. Findings from this Delphi suggest that successful elicitation support for the "fluid and dynamic" context of both on job learning and initial education requires careful adaptation of support to multiple team and context dimensions. Proficiency is not seen as critical for collective problem solving but the pro-active learning attitude and openness towards the knowledge expressed by others. Complementary to the literature review is the great weight experts put on explicitly embedding and relating concerted supportive action to the surrounding context. In their view supportive action always has to clearly articulate its added value for the specific situation.

The prominence of knowledge productivity issues is in line with massive attention for knowledge construction in organizational contexts (Davenport & Prusak, 1998; Brown & Duguid, 1998) and emerging attention for knowledge productivity (Kessels, 1996) in both professional and academic learning (Leinonen et al., 2002; Scardamalia & Bereiter, 1996).

More restrained is the attention paid in the Delphi study to the aspect of supportive action for personal competency growth and grounding. Both aspects are prominently present in research literature on collaborative computer mediated learning and working (Beers, Boshuizen & Kirschner, 2003; Fischer & Mandl, 2001; Mulder et al., 2002). In the Delphi debate however various opinions co-existed regarding nature, importance and support of relevant individual knowledge. For some

business practitioners especially, the support of the individual team member by way of the provision of knowledge inventories was crucial. In particular the academics include individual knowledge competency growth and grounding in the broad range of context affordances decisive for both individual and collective competency growth and task performance. Here we observe incongruence. The difference in perceptions might possibly be caused by the fact that the Delphi study brought together academics and business experts who address the issue of emerging open learn-work settings from a different position.
To summarize, this Delphi investigation delivered relevant extra input for the design of scenarios to augment collaborative elicitation. Experts stress the great importance of a pro-active learning attitude of all team members as a crucial precondition. They perceive supportive action as something directly connected and matched with the project context. Two guidelines emerge from this Delphi study. The first is to pay as much attention to content and functionality of supportive action as on the articulation of its added value in a perfect fit to the specific situation. The second is that simple one-dimensional tools are worthwhile for prototyping, lab testing, and theory development but should be embedded into multidimensional support scenarios to be successfully in real life settings.

In the second study we explored the perception of a representative user group, graduate students working on a real life task in a real or simulated work-learn environment. We haven't been able to discover the hypothesized significant differences of expert and novices as we expected from studying available literature. A majority of the respondents preferred self-activation of support both for domains in which they are proficient and for domains that are new to them. Both groups opted for textual support as the primary and most important mode for elicitation support. Respondents are interested in argumentative elicitation support, even though they didn't yet seem to grasp the added value of the Toulmin based argumentation method proposed. Possibly due to this indistinctiveness they didn't expect significant effects.

Limitations

Some critical remarks about both studies have to be made. Both studies had a small number of subjects (both < 25 persons). Hence to get sound evidence these findings should be reconfirmed by other investigations based on samples with substantially more subjects.

Study 1 was a Delphi, a qualitative study. A method, which might generate atypical and unbalanced results under the deceptive appearance of “objectivity” and “representativity”. Therefore, we took the aforementioned precautions to guarantee a balanced design. Results still might be biased slightly by the intrinsic dynamics of an open debate and the interpretations of the researchers. The careful selection of the experts plus concern for appropriate enabling conditions for a free format debate offered the necessary opportunities for an unprejudiced articulation of representative views. It cannot prevent the fact that articulated ideas and their interpretation will always be somehow “time-stamped” and “situation-dependent”. Thus on the observations of a sole Delphi study; the small group involved, the open nature of the Delphi method and the qualitative nature of the data, no far reaching conclusions should be drawn.

For these reasons we placed the results of the Delphi study in the frame of reference derived from literature. In sum although the Delphi approach yields much data in an open way, and provides relevant insights, we need to be conscious of interpretative biases causing reliability problems. Therefore it is necessary to stay alert to further underpin our interpretations with references to findings from other data sources such as literature studies and reports on controlled empirical studies.

In the second study, the Toulmin approach used might not have been so evident enough for the participants that they were able to give well-grounded ratings of it.

Implications for further research

All in all, in contrast to what we expected, the proficiency dimension doesn’t seem to be as significant and crucial as we assumed. Results don’t confirm our main hypothesis. At the same time, the Delphi study puts forward the importance that supportive actions should address in a concerted way multiple dimensions relevant to that specific instantiation of collaborative learning. The implication seems to be that not one factor, such as the proficiency of a team member, is decisive for effective elicitation support but the attunement of all key dimensions to the particular task at hand, the team characteristics and it's context.

The articulation support preference seems not to be discriminated by a single factor, like expertness but by a compound complex of factors. Factors manifested at the personal, the team and the context level contribute to effective knowledge communication in teams. Factors emphasized by the experts are in line with this assumption. Interacting factors such as a person's team attitude, expertise, proactive or reactive learning attitude and need for structuration are mentioned at the personal level. At the team level decisive influence of team composition and shared team objectives are assumed.

Together these studies indicate the importance and interdependencies of multiple and compound factors that are critical for the design of successful elicitation support.
Further research is required. Preferably further research should try to use fine-tuned combinations of research methods for complementary underpinning of evidence found.
First further exploration is needed in the relation between the key variables mentioned, their nature, strength and interdependence. Secondly empirical research is needed to investigate the actual strength of the affording variables in actual team performance. Multiple tests will be needed to empirically test which mix of multidimensional support generates an optimal effect on the collaborative learn-work performance. Meanwhile the combined findings from these studies and other qualitative and quantitative studies might help to make progress with respect to adequate modeling of the complex of decisive factors determining the effect of knowledge articulation support for co-construction of knowledge in the act of collective performance.

Appendix 3.1 Summary of statistics for Toulmin based elicitation preferences

Question content	Expertness	N	Mean	SD	*p*- value*
Need for electronic support	expert	14	2.50	.85	0.77
	novice	9	1.67	1.12	
Importance of systematic argumentative elicitation	expert	8	2.63	.92	0.69
	novice	7	2.43	.98	
Use of systematic argumentative elicitation	expert	14	1.71	.83	0.35
	novice	9	2.11	1.05	
Intricateness of systematic argumentative elicitation	expert	6	1.50	.84	0.48
	novice	6	1.83	.75	
Toulmin delivers insight in arguments for my proposals	expert	12	.42	1.00	0.22
	novice	8	1.13	1.36	
Toulmin model facilitates collective decision taking	expert	12	.33	.77	0.13
	novice	8	1.13	1.24	
Toulmin model didn't help for knowledge communication	expert	12	.33	.78	0.08
	novice	8	1.25	1.16	
Learning to use Toulmin is easy	expert	12	.42	1.00	0.32
	novice	8	.88	.99	
Retrieving peer argumentations is necessary for collective decision taking	expert	12	2.00	1.54	0.85
	novice	8	2.13	1.36	
Knowing peer argumentation enables effective contributions to collective choice	expert	12	1.75	1.36	0.83
	novice	8	1.88	1.25	
Earlier recognition of ideas when arguments are explicitly articulated	expert	12	1.58	1.31	0.80
	novice	8	1.75	1.49	
Toulmin model enables insight in peer argumentation	expert	12	.33	.77	0.11
	novice	8	1.00	.92	
Electronic argumentation support, eliciting peer arguments is advantageous for collective decision making	expert	12	1.17	1.19	0.89
	novice	8	1.25	1.49	
Electronic argumentation support, to articulate own arguments is advantageous for collective decision making	expert	12	1.17	1.19	0.74
	novice	8	1.38	1.51	
Quality final collective result is better than individual result	expert	14	1.50	1.09	0.43
	novice	9	1.78	.83	
Need for electronic support to phrase ideas	expert	14	1.71	.99	0.33
	novice	9	1.33	.71	
Need for electronic checklist support	expert	14	1.86	.86	0.82
	novice	9	1.78	.83	
Need for electronic support to draw ideas	expert	14	1.43	.76	0.72
	novice	9	1.33	.50	
User-activated support for domains in which I am a novice	expert	14	1.64	.50	0.91
	novice	9	1.67	.50	
User activations for domains in which I am proficient/expert	expert	14	1.93	.27	0.76
	novice	9	1.89	.33	

Note: *p*-value based on t-test.

CHAPTER 4 – Structuration support for knowledge elicitation in distributed learning groups[1]

Abstract

Finding common ground for knowledge articulation in collaborative work is difficult. Studies suggest that structuration support helps teams to overcome articulation problems. Based on results of prior investigations we have developed a dedicated elicitation instrument the 'Ideasticker'. New is that this post-it like elicitation instrument, offers structure to elicit not only the proposition itself, but also the underlying argumentation and the added value of the idea in the ongoing debate. We hypothesize that structured insight into one's teammates ideas might facilitate the process of finding common ground. In a within-subject design 19 students worked first without elicitation support, next the Ideasticker was offered. The study did not generated quantitatively speaking the predicted straightforward positive effect of the Ideasticker treatment. Yet students express high expectations of this type of elicitation support, provided that it covers their elicitation and structuration needs during the entire knowledge building process.

Introduction

Collaborative work on complex ill-defined problems has become salient for professional work. To timely find innovative and sustainable solutions for complex problems in a rapidly changing world multidisciplinary teams are formed. (Allee, 1997; Davenport & Prusak, 1998; Drucker, 1992; Kessels, 1996; Kogut & Zander, 1992; Kurtz & Snowden, 2003). Teams work on a whole range of complex, ill-structured problems, varying from the design of technological advanced commercial products or services (Bragge, Marttiin & Tuunanen, 2005) to policy reports addressing complex societal issues (Bekkers & Lips, 2001). To achieve the best possible solution, relevant insights of individual team members have to be considered for integration into team knowledge, underlying team performance.

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[1] Bitter-Rijpkema, M. E., Martens, R. L, Jochems, W. M. G., & Van Buuren, H. *Structuration support for knowledge elicitation in distributed learning groups*. Manuscript submitted for publication.

Prior research points to the vital importance of individual team member's unarticulated domain expertise and problem solving heuristics for the quality of team performance (Boisot, 1998; Cooke, 1999; Cooke, Salas, Cannon-Bowers & Stout, 2000; Leonard & Sensiper, 1998; Orr, 1996; Sveiby, 2001; Von Krogh et al., 2000; Zack, 1998).

The problem is that in natural problem solving settings individuals don't feel a direct need to articulate their implicit knowledge (Cooke, 1999; Hutchins, 1995; Land, Aurum & Handzic, 2001; Mulder, 2004; Stenmark 2001). In addition it proves to be difficult to estimate the value of your implicit knowledge for your peer's understanding, since it is so self-evident to yourself.

Recognizing the value of this type of knowledge for team problem solving, this paper addresses the issue how to enhance explicitation of relevant individual knowledge, with the aim to find common ground for further decision-making and co-construction of team knowledge underlying team result.

We will first define relevant concepts and introduce prior research regarding methods to prompt for knowledge elicitation. We then describe the functionality and design rationale of the *Ideasticker*, as our elicitation support tool to be used in settings of computer supported teamwork. We executed an experiment to explore the possibilities of this type of elicitation support, and assess its use and appreciation.

Prompting for knowledge elicitation

Solving ill-structured problems in teams is a core element of today's professional work. The same holds for the competence development for a professional career in the final stages of university education. Characteristic for professional practice is a complex mixture of cognitive and social processes underlying a team's knowledge creation and decision-making (Klein, 1998). The problems to solve are often, open ended without a single solution or a single solution path. (Conklin, 2003; Lave & Wenger, 1991; Schön, 1983). In these settings the team solution gradually emerges from the team members' individual input, followed by exchange of perspectives, to discussions and negotiations to find common ground for decision-making and collective performance. Individual contributions consist of both not yet articulated domain knowledge and strategic problem solving heuristics.

With the emerging prevalence of team based work and learning many researchers investigate methods to support collaborative problem solving by prompting or scaffolding peer interactions (Feltovich, Spiro, Coulson & Feltovich, 1996; Jonassen & Hernandez-Serrano, 2002).

Several authors like Cooke (Cooke, 1999; Cooke, Kiekel, Helm, 2001) and Stahl (2000a) describe how individual knowledge and team knowledge emerge and evolve in interaction with each other. In line with Nonaka (1995) the emergence of a "team knowledge" is described by Cooke (Cooke, et al., 2001) and Fischer (Arias, Eden, Fischer, Gorman & Scharff, 2000) and Stahl (Stahl, 2000a) as a construction process going back and forth between tacit and explicit stages, moving back and forth between individual contributions and the team discourse delivering articulated knowledge available to the whole team.

Within the context of distributed cognition, several studies suggest to address knowledge communication problems in distributed teamwork via structuration aids. These researchers propose more or less formal text structures or representation formalisms for the individual team member's contributions to the team debate (Beers, Boshuizen & Kirschner, 2003; Chi, Bassok, Lewis, Reimann & Glaser, 1989; Chi, et al., 1994; King, 1991; Plötzner & Fehse, 1998; Van Bruggen, Boshuizen & Kirschner, 2003).

Positive effects have been reported of content based structuring, both with adolescent students (Chi et al., 1989; Fischer, & Mandl, 2001; Plötzner, Dillenbourg, Preier & Traum, 1999; Plötzner & Fehse, 1998; Puntambekar & Kolodner, 1998) as with adult professionals (Selvin, Buckingham Shum & Sierhuis, 2001a). Prompts to enhance strategic questioning and reflective thinking (King, 1991) and representational aids to surface underlying arguments and evidence (Carr, 2002; Cho & Jonassen, 2002; Suthers, 1999; Van Bruggen et al., 2003) tend also to sort positive effects.

Various elicitation methods for collaborative work and learning have been tested (Chi, et al., 1994; Jeong & Chi, 2000; Selvin & Buckingham Shum, 2000). Studies thus far however didn't disclose the precise conditions for customization of prompts to the needs of working professionals. Most empirical investigations have focused on domain specific prompting. Empirical evidence has yet to be gathered with respect to other dimensions, such as personal and group characteristics, like expertness, personal preferences and other context variables. Aforementioned studies primarily describe effects of domain specific methods that try to scaffold domain understanding. Use of content-based scaffolds proved to be successful to elicit solution steps of distinct problems but didn't yet generate similar outcomes with ill-structured collaboration problems. A special procedure to trigger articulation of process reflections has been proposed by Gott (Hall, Gott & Pokorny, 1995) in the PARI (Precursor [reason for action], Action, Result, Interpretation [of result]) procedure. This method addresses reflection on prior reasons for action, articulation of underlying arguments and result expectations. In this way individuals are asked to reflect on the position of their ideas and actions during ongoing task performance. Since Gott observed performance improvements caused by PARI-based reflections and articulation we decided that elicitation of these specific dimensions might also enrich collaborative knowledge development. Positive results of separate content- and process-oriented elicitation support gives ground to expect the same or stronger effects of multidimensional triggering combining content and process stimuli (Jonassen & Hernandez-Serrano, 2002). The question now is whether a combination of both approaches into a single instrument indeed generates positive performance effects, when students collaboratively construct knowledge for the joint solution to an ill-structured problem. We therefore designed a multidimensional elicitation-triggering tool, the *Ideasticker*. To investigate the instrument's use, its perception and effects we inserted the elicitation enabler into a newly designed e-learning space (Kreijns, Kirschner & Jochems, 2002) of a graduate social sciences course. Guidelines for the design of the *Ideasticker* were derive from the theory of situated learning (Brown, Collins & Duguid 1989; Lave & Wenger, 1991) and distributed cognition (Cooke et al., 2001). This implies that supportive action has to be contextualized and should match the knowledge communication needs of that particular team.

Consequently our intervention had to fit the particular team's context, objectives and members' expertness (Bitter-Rijpkema, Martens & Jochems, 2002). At the same time the knowledge elicitation enabler had to be simple and easy to use. Furthermore it should offer added value in the perception of the user. Therefore the tool had the format of a template as easy to use as Word, with separate structured fields for chat, content, process, and further requirements information.
In this way the treatment is supposed to enable a rapid disclosure of differences and similarities between articulated individual propositions, enhancing the emergence of common ground for collective decision-making.

Against this background it is hypothesized that:

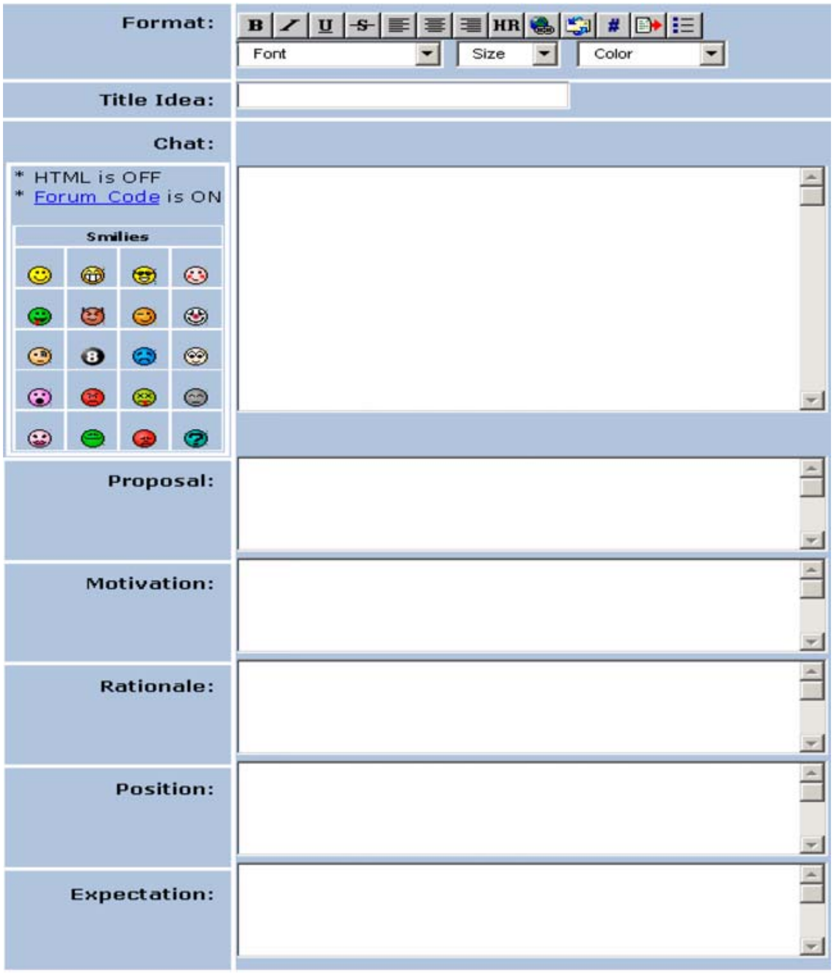
1: Students will rate the 2nd phase with *Ideasticker* elicitation support higher than the 1st phase without elicitation support.

2: Students with a novice-like work attitude will rate the support condition higher and will be more positive about the support than students with a proficient or expert profile.

3: The appreciation of the situation with support might differ according to personal attitudes towards teamwork. Scores for collaborative openness and trust, knowledge sharing and collaboration will positively correlate with this appreciation. Scores on intra-group conflict scale will correlate negatively with this appreciation.

In the experiment the functionality of the support tool was at the fore, to explore differences between a situation with and without knowledge elicitation triggering. The independent variable is the use of the knowledge articulation support tool developed. We studied frequency of use, students' perception of the collaborative problem solving process and their perception of the quality of contributions. Next the respondent's appreciation of the actual functioning of the support tool and its potential for future use are analyzed.

Figure 4.1 Screenshot Ideasticker[Ω]



[Ω] Acknowledgement: Ir. W van der Vegt (OTEC) developed agile versions of the *Ideasticker* elicitation functions for Studynet, Blackboard and Snitzforum.

Method

Instrument

Since insufficient articulation of a team member's propositions, underlying arguments and result expectations cause unnecessary misinterpretations during the co-construction of common ground for collective action, an elicitation enhancer, the *Ideasticker*, was designed. This tool combines triggers for systematic articulation of relevant process and content knowledge. For ill-structured problem solving tasks, the *Ideasticker* tool supports collaborative task execution by prompting team members first to systematically articulate their propositions and underlying rationale, followed by a positioning of the actor's expectations regarding their contributions (Chi et al., 1994; Gott, 1995). A Snitzforum based version of the *Ideasticker*, as depicted in Figure 4.1, has been developed to suit the Snitzbased workspace of the teams (Kreijns, 2004).
The *Ideasticker* provokes systematic articulation via separate fields for respectively chat, proposition, underlying arguments, estimated effect, required actions and requested response. These structuration options are available for both posting new ideas as well as replies to existing ideas.

Participants

Participants were graduate distance students in Social Sciences from the OUNL working in a dedicated learning environment on an integration task: the design and execution of a research project.
The experiment started with 22 adult participants. Three students left the project at a very early stage, due to private circumstances. Their data haven't been taken into account. Nineteen respondents finished the experiment. The group consisted of one male and eighteen female respondents, between 31 and 66 years of age. Students volunteered for the course. The expertness indication instrument used in this study approximates the expert-like or novice-like profile of participants via scales used in prior experiments (Bitter-Rijpkema, Jochems & Martens,

2005). As proficient professionals ("experts") are considered those who score as an expert having a vocational educational background and expert self-perception. In addition they score as experts on a majority of other dimensions, being: perceived peer perception, self-reliant proficiency, expert-like work habit, and professional practice within the domain. As novices were rated those participants who scored both as newcomers on a majority of the aforementioned dimensions, including educational background (with only initial training) and a (novice) self-perception. According to this expertness approximation eleven of the students were characterized as novice, whereas seven had a proficient professional (expert-like) profile. Respondents didn't have a prior history as a group. But most respondents (52.4%) shared some experiences with peers, since they had already worked once with some other team members.

Procedure

Students collaboratively had to solve a complex ill-structured problem: the development of a research plan. Participants were divided into four teams. The team size ranged from 4 to 6 persons. Each group had to fulfill the same task. The collective task was divided into two phases each with two subtasks. In the first phase students had to discuss the research objective, propose a research hypothesis and decide on the research plan. Next they had to reach agreement on a collective coding scheme for the dialogue analysis. In the second phase students first applied their discourse analysis scheme. Finally each group reported their results.

The experiment had a within-subject design. During task execution team members had to discuss their views on existing options. They had to negotiate the integration of their input into the collective proposal. At the start of the second phase the *Ideasticker* tool was offered. Prior to the use the rationale of the *Ideasticker* was explained to the students in a fact sheet, represented in Figure 4.2.

Figure 4.2 Fact sheet: the Ideasticker explained

> The what, why and how of the *IDEASTICKER*
>
> Your learning environment includes an additional functionality: the *Ideasticker*. This *Ideasticker* aims to support your collaborative dialogues while working on problem definition and problem solving. It asks you to describe not only your proposal itself but also articulate underlying arguments for it, and share your expectations and remaining questions with your peers. We invite you to use and test the *Ideasticke*r and report your experiences. Finally we are interested to hear your suggestions for improvement of the *Ideasticker* at the end of this project.
>
> *WHAT is the Ideasticker?* The *Ideasticker* is an aid to structure you're communication while working on a collective task. It has the format of a message in the Snitzforum that contains, apart from a generic field, some dedicated structure fields. Those special fields offer support to exchange specific dimensions of your idea. Research indicates that elicitation of arguments and expectations of your propositions helps to effectively and efficiently achieve collective performance.
>
> *WHY should I use the Ideasticker?* Miscommunication proves to be one of the main causes of collaboration problems. We expect that elicitation of individual perspectives and underlying rationales will minimize the causes of misunderstanding and helps to create a shared understanding for collective performance.
>
> *HOW does the Ideasticker works?* Activate the button *New Idea* when you want to introduce a new idea or proposal. Use the specific structure fields for your task related input. Use the open chat field for generic messages and social talk.
>
> Present your proposal using the structure fields
>
> - I propose: here you describe your proposition.
> - Because: the field to elicit arguments, motives or reasons for your claim.
> - Evidence: field to report available evidence supporting your proposal.
> - Expectations: elaboration on expected results. Why should your peers go for your proposal?
> - Actions needed: indication of how your proposal relates to earlier and other suggestions. Indication of required actions. Suggestions for the optimal way to organize action.
> - Response requested: indicating the type of reaction you demand.
>
> Depending on the state of the debate you as a user decide which fields are relevant.
>
> *Sending and replying* You post your contribution in the same way as posting any other posts. To reply you use the button *reply to idea.* This option generates a dedicated prestructured reply format with the structured post. It enables you to easily indicate on which components of the idea you want to comment.

Students were urgently asked (but not compelled) to use this tool for their propositions and dialogues. Two respondents didn't fill in all sections of the questionnaire, nor did they use the *Ideasticker*. Consequently the opinions regarding those sections stem from 17 respondents. During the experiment students worked collaboratively on the design and execution of a research plan to investigate social and cognitive interactions in distributed learning groups. Students had no knowledge elicitation support (the without *Ideasticker* condition) at their disposal, during the 1st phase of collective task execution. In the 2nd phase students were offered elicitation support (the with *Ideasticker* condition).

Materials

Prior and posterior to task execution we administered questionnaires to investigate relevant user perceptions. The pre-task survey (63 questions) focused on initial attitudes towards collaboration, learning, knowledge exchange and elicitation support needs. The post-task survey (83 questions) assessed the use of the *Ideasticker* and related changes in attitudes on dependent variables.
Students were asked to fill in the pre-and post-task questionnaires prior to the face-to-face opening and closing sessions of the course. Completing each questionnaire took about 15 minutes.

We used scales (with a Cronbach Alpha of >.50) either tested in earlier experiments (Bitter-Rijpkema, Jochems & Martens, 2005) or existing scales (Bulach, 1993; Hackman, 1976; Nielsen, 1993; Saavedra, Early & Van Dyne, 1993; Savicki, Kelley & Lingenfelter, 1996) adapted from computer supported work and group learning research. An overview of scales used is presented in Table 4.1.

Table 4.1 Overview of scales used

Scales used ^	Items	Cronbach Alpha
Collaborative openness and trust scale (Bulach, 1993)	6	.71
Collaboration attitude scale (Savicki, et al., 1996)	5	.75
Knowledge sharing attitude (Bitter-Rijpkema et al., 2005)	6	.85
Novice-like work attitude (Bitter-Rijpkema et al., 2005)	2	.82
Expert-like work attitude (Bitter-Rijpkema et al., 2005)	4	.69
Task strategy scale (Saavedra et al., 1993, Hackman, 1976)	5	.92
Intra-group conflict scale (Saavedra et al., 1993)	6	.80
Tool usability scale (Nielsen, 1993; (Bitter-Rijpkema et al., 2005)	5	.64
Ideasticker potential scale (Bitter-Rijpkema et al., 2005)	4	.92
Knowledge communication scale (Bitter-Rijpkema et al., 2005)	7	.93

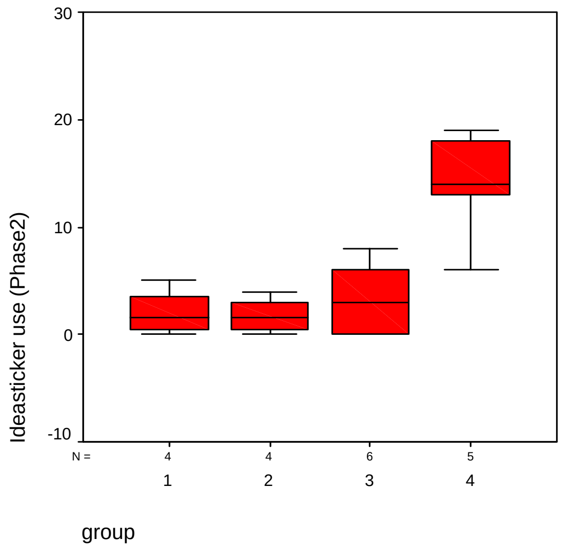
^ All scales consist of 5-point Liker scale items

These scales were used to approximate individual expertness and characterize personal attitudes with respect to knowledge articulation, team collaboration and support. Right at the start students were introduced to the electronic learning environment in which their collaboration would take place. Specific affordances (Kreijns, Kirschner & Jochems, 2002) were introduced into the learning environment, to enhance cognitive and socio-emotional interactions. To augment social awareness and sociability, the use of emoticons was promoted. Participants in this experiment worked in a different learning space as the "Studienet", their regular electronic learning environment, to which they are used. During the experiment information regarding the learning environment in general and the *Ideasticker* in particular was on-line available. Aside of this, participants could contact helpdesk persons in case any problems or questions arose.

Results

In sum the *Ideasticker* was used 98 times, with a large variation in intensity of use across the groups and individuals, as can be concluded from the distribution of *Ideasticker* use per group, presented in Figure 4.3.

Figure 4.3 Frequencies of Ideasticker student use per group



Group 3 and especially group 4 were "heavy" users of the *Ideasticker*, whereas on the other hand use in group 1 and 2, was minimal. The interpretation of scarce use in the 2nd group should take into account the fact that this group did malfunction at that time due to internal conflicts, prior to the treatment phase.

Within the four groups tool use differed substantially among individuals. Two persons in group 4 generated 35.8% of the *Ideasticker* use. Whereas group 3 generated 21.4% of sticker use and group 4 produced 35.7 % of sticker use. An example of the *Ideasticker* postings is shown in Figure 4.4.

Figure 4.4 Example of Ideasticker message

Idea: ANALYZING DIALOGUE DATA.
Printed from: xxxx / groep-4 Topic URL: http://inf.ou.nl/snitz_XXX-6_groep-4/topic.asp?TOPIC_ID=132
Printed on: 03/11/2003 Topic author: Mrs Xr Subject: Idea: Analysis dat Hans
Posted on: 01/23/2003 14:16:04 Message:
Chat: Hi colleagues, I have been busy this morning to produce wonderful SPSS output but I now have to analyze the output generated.
Proposal: I propose to see what conclusions I can draw from these data output. I will publish the results in the news forum first thing tomorrow morning. Everybody is invited to constructively criticize the results as presented and propose further improvements. At the same time I will indicate things unclear to me, problems I experience, and my questions.
Argumentation: I think I will not only be able to present results, but many questions as well.
Evidence: I'm in the process of gathering evidence. Don't forget I am not very strong in this!
Expectations: Please execute concurrently your analysis, if you have time. In this way we will have the opportunity to compare results.
Actions: My actions will be: file exchange, cross tabs, analysis of results. I will report findings and questions in the discussion forum. I want the other team members to execute their analysis of data and report them too.
Request: I ask you to comment on my report. And compare our results!
Reply by Mrs XYZ: Topic author: Mrs.XYS Replied on: 01/23/2003 19:21:57 Message:
Chat: Hello, I have placed the dialogue analysis report in our group's file cabinet. See the results of a hard day's work. Now I have the evening off, looking forward to your reactions. Who knows may be I am totally wrong in my assumptions. Let me know! Bye.
Expectations: Think with me. Help us to co-construct a collective result.
Actions: Get my report file. Investigate and report your comments on my analysis.
Request: Annotate my documents and answer my questions
X-6 / groep-4 : http ://inf.ou.nl/snitz_xx_groep-4/© Open Universiteit Nederland

The *Ideasticker* messages constitute only a relatively small proportion (19,2 %) of the overall communication (ca 52 postings) that took place during the 2nd phase (the with *Ideasticker* condition). Respondents rated their appreciation of knowledge communication for both conditions on a 10-point scale.

Table 4.2 Analysis of Ideasticker rating (one-way ANOVA)

Rating	Group	N	Mean	SD	SE	*p*- value
Phase 1	1	4	6.00	.81	.40	
	2	4	3.50	1.73	.86	
WITHOUT Ideasticker	3	6	7.33	1.75	.71	.005
	4	5	6.60	.89	.40	
	Total	19	6.05	1.92	.44	
Phase 2	1	4	5.75	.50	.25	
	2	2^	4.00	2.82	2.00	
WITH Ideasticker	3	6	5.33	1.50	.61	
	4	5	6.60	.89	.40	.16
	Total	17	5.65	1.45	.35	

^No response to one section by 2 students.

Investigation of the quantitative data as depicted in Table 4.2 show how the distribution of ratings and their evolution within and among the groups varied. We assumed in the 1st hypothesis that groups would rate the *Ideasticker* condition significantly higher than the no treatment condition. Results however don't show the predicted changes. Hence hypothesis 1 has to be rejected.

To gain insight into underlying reasons for the decrease in the rating of the "with *Ideasticker*" period we explored the qualitative information gained from open comments in the questionnaire, respondent's process reports and the post-task group interview. Analysis of these data show that respondents express overall comments when asked for feedback on elicitation issues. Their feelings towards elicitation support were completely embedded into the overall team learning experience. Exemplary is the statement of one of the students describing that "….during task execution we had a multitude of activities to do. This took our team energy astray from deep discussions…" [2]. In the process-reports and face-to-face evaluation session several students stated that they perceived the joint task as complex and really demanding.

[2] Translation of remarks originally made by students in Dutch.

Students felt they had to work at the edge of their abilities. The task required them to work with great autonomy, employ high order problem-solving skills, concurrently collaborating under time pressure. The logged dialogues demonstrate how tensions between team members rose over time. One respondent articulated her growing irritation as follows: "I disagree with the way we are collaborating and working together at this moment, as you might have noticed already from my mail messages yesterday. In my view it is improper when you post initial corrections as definitive, without prior consultation and mutual agreement".[4] As you notice from this example students got very critical towards each other over time. Progressively, initial positive perceptions faded. Peer input was valued as to whether it would directly sort effect to meet nearby deadlines and generate desired outcomes.

The individual comments though show a more balanced judgment of the *Ideasticker* functionality. Students state, "posting comments has to be easy, offering clear cues, which is the case with the *Ideasticker*". They tell "some structuration of contributions is useful for clarification of ideas and negotiation of actions and opinions". Yet the "*Ideasticker* structuration shouldn't be too detailed", "it should have a simple format" and "it should always be available" and user-activated.
The second hypothesis states that a person's expertness profile might influence use and perception of the elicitation support offered. We hypothesized that students having a novice-like profile probably are more in need of support and hence will be more positive towards support than students with an expert-like profile. Accordingly, we expect novices to rate the phase with *Ideasticker* support higher than students with an expert-like profile.

Evidence gained in this study doesn't support our assumption. Results presented in Table 4.3 show that novices changed their rating for the second phase downwards. At the same time the rating of participants with an expert-like profile did not change.

Table 4.3 Expertise related rating of the treatment no treatment situation

Ratings	Expertness	N	Mean	SD
Without Ideasticker	Novice	11	6.55	1.63
	Expert	7	5.38	2.20
With Ideasticker	Novice	9^	5.89	1.26
	Expert	7	5.38	1.68

^ No response to one survey section by 2 students.

Likewise the descriptive statistics with respect to the *Ideasticker*'s usability, effect and potential, reported in Table 4.4, don't reveal noticeable differences between novices and experts. Notice that subjects, in general, responded in rather neutral terms. Consequently we haven't found evidence supporting hypothesis 2.

Table 4.4 Expertness dimension and Ideasticker appreciation

Ideasticker appreciation	Expertness	N	Mean	SD
Ideasticker potential	Novice	11	3.18	.90
	Expert	7	3.39	.85
Ideasticker effect perception	Novice	9^	2.75	.81
	Expert	7	2.75	.77
Ideasticker Tool usability	Novice	11	3.43	.99
	Expert	7	3,42	.51
Ideasticker based knowledge communication	Novice	9^	3,26	.92
	Expert	7	2.91	.81

^No response to one survey section by 2 students.

In addition to our request to score both the treatment and no-treatment situation we asked the participants to indicate how they perceived the quality of knowledge communication under both conditions. We used a seven-item scale for knowledge communication quality, measuring (Cronbach Alpha .93) whether respondents understand each other's proposals plus arguments and whether respondents felt that all relevant ideas had emerged in an efficient and effective way. Student's individual perception of knowledge communication over the two

conditions did not differ significantly for the treatment condition compared to the no treatment condition.
Finally in the 3rd hypothesis it is assumed that positive attitudes towards collaboration, knowledge sharing, communication openness and trust, as measured via the aforementioned scales (Table 4.1), would nurture a more positive reception of the elicitation support offered, whereas the intra group conflict perception (Table 4.1) would negatively influence the reception of the *Ideasticker*. Exploration of correlations between these attitudes and the *Ideasticker* reception however didn't sort any significant effects.
We noticed that, in both pre and post-task questionnaires, responses were predominantly centered into or next to the neutral category, with no significant changes for perceived knowledge communication qualities.

Analysis of the additional qualitative information helps to explore these findings. Qualitative data in this study consisted of information regarding task execution via logging of all communication in the electronic learning system, and respondents' evaluation reports, personal comments on open questions and their input to the group evaluation during the closing session of the project.
These data sources reveal that miscellaneous group conflicts and problems played a decisive role in group processes and project perceptions. Students report that the task autonomy given to them with the need to collaborate around a rather complex task was at the edge of their capabilities. This caused quite some problems already early on in the 1st phase, problems, which for example in the 2nd group caused a drop out of two persons, who went on to work separately. All groups reported substantial difficulties to timely reach firmly rooted collective decisions. Consequently, negative feelings about existing issues tended to linger on. Coordination and task-time-execution stress accompanied the teams as time went on. As a result team members tended to focus more on keeping a collective equilibrium and sustain progress towards result than on intensive exploration of interesting options and possible alternatives.

In their comments a majority of students state that a more compact version of the *Ideasticker* would really be an add-on. As one respondent states “the *Ideasticker* is really great but it can function better in a more compact format since sometimes a simple yes will do, and often we only need to know what is proposed, why and by whom”. However, for the idea generation and deliberation phases of collaborative work on ill-structured tasks students see a surplus value for structuration support. One respondent took a totally different position having an antipathy against any external scaffolding, disliking any intrusion into her preferred work style. Several students report that they don’t see “why new ideas should be structured immediately”, since their ideas evolve gradually. Students indicate that ideas only materialize after articulation of initial vague notions. They crystallize in the discourse. Hence structuration support is only helpful when, in the initial phase of idea generation, it leaves enough space for open associative explorations. According to several participants structuration support using a pre-organized format makes sense once concepts already have started to crystallize. Supportive action should recognize these constraints. Gradual and flexible structuration support is expected to create value for knowledge communication.
To conclude we can say that respondents have expressed positive expectations for elicitation support. A compact but dynamical *Ideasticker* tool is desired, delivering informal and open support for the initial stages of work. Furthermore it should be able to evolve and adapt to the needs in subsequent phases of teamwork.

Discussion

In this study an elicitation support, combining content-based and process-based articulation triggering, has been tested. The elicitation support was embedded in an authentic computer supported collaborative learning (CSCL) environment. The objective was to investigate whether the introduction of the *Ideasticker* tool for structured argumentation and expectation elicitation generated the predicted changes. Generally speaking this experiment did not show statistical significant changes directly and only caused by the elicitation enabler introduced in collective teamwork. Investigations of Chi (Chi, De Leeuw, Chiu & LaVancher, 1994), Gott (1995) and Plötzner (Plötzner, Dillenbourg, Preier & Traum, 1999) sorted some significant effects due to content or process elicitation support with students working on well-defined tasks. Our findings however are more in line with observations of Weinberger (Weinberger, Fischer & Mandl, 2001). They investigated effects of elicitation scripts in less well-structured course settings. They too didn't find the expected outcomes but observed increased knowledge constructive interactions between student dyads when triggered to elicit their ideas via an "explain teach back" script. The same type of confounding results are reported in other experiments (Van Bruggen et al., 2003) when investigating knowledge elicitation prompts with ill-structured tasks in open and authentic computer supported settings for learning or working. With hindsight we might have been too ambitious to address the rather complex phenomenon of knowledge elicitation prompting immediately in an authentic setting, with students working together on a demanding ill-structured collaboration task in a new electronic course setting.

The following considerations are important to take into account when explicating the results found.
First, we have to be aware that students confounded their perceptions of elicitation support with their overall feelings towards task collaboration and work environment. Their open comments revealed this. The combination of given autonomy, task complexity, distributed work requirements and time constraints overburdened the group's actual abilities. Hence participants didn't separate their overall feelings from the specific *Ideasticker* related aspects. Participant's general frustrations negatively influenced both use and reception of the *Ideasticker*.
The *Ideasticker* has been tested in an authentic course environment on a complex task, which students perceived as very demanding. In addition participants experienced a short time-task performance span, given the additional need to accommodate to virtual teamwork in a new learning environment. In such a demanding setting students expect elicitation

support to be available right from the beginning, which wasn't the case, due to the within subject design of the experiment. Problems to timely reach collective decisions caused teams to proceed more and more in a cautious, safekeeping mode, a rather unrewarding soil for creative explorations. Consequently these aspects introduced disturbing factors into our elicitation investigation.

Secondly, we probably haven't found clear and statistically significant effects of the elicitation triggering tested, due to the compound nature of the phenomenon under investigation. Determining factors to enhance knowledge elicitation seems to be more complex and interdependent than we initially assumed and have addressed with our treatment. Participants indicate in their open comments that optimal elicitation support for collaborative task performance on ill-structured tasks requires more meticulous supportive actions per phase of collective task performance than the *Ideasticker* offered. To support articulation, a tool needs to change for the various problem-solving phases. The *Ideasticker* addressed the structuration needs via a single format to communicate ideas and find common ground for decision taking. Thereby, we implicitly assumed that already from the start onwards students are able to articulate underlying foundations of the issues submitted. Participants however indicated that this is not the case. Initial articulation starts from multiple vague notions, which differ from mature statements. Initially these ideas might not be more than suggestions, preliminary questions regarding possible options, or articulations, which are still too imprecise to benefit from clear-cut structuration.
The remarks of our participants are supported by recent publications on the evolution of knowledge in communities. These indicate that there is a need to support incremental structuration, recognition and evolving knowledge building in persistent conversations (Crutzen, 2000; Fischer, Grudin et al., 2001; Snowden, 2002). A different support is necessary in the initial stages of idea generation, when ideas are still very vague and communication constitutes primarily of explorative and coordinative dialogues. Supportive actions in this phase should flexibly address the

predominant needs of that moment, bootstrapping informal articulation to help team members communicate the early seeds of their ideas. Next the support should nurture the evolution of individual contributions to mature into team knowledge for collective performance. Flexible structuration options have to take care of the incremental formalization of ideas already brought to the table. Thus enabling them to merge into the pool of collective knowledge artifacts needed for a joint performance (Cooke, Kieke & Helm, 2001). During the evolution of initial seeds of thought into mature components of collective team cognition structured dialogues should care for comprehension and effective communication between peers. (Chi et al., 1994; Plötzner, Dillenbourg, Preier, & Traum, 1999).
It is via this method of incremental transformation that articulation support might have the predicted potential. Participants in this experiment indicated that articulation enhancers substantially add value to the clarification and communication of one’s ideas to teammates, provided that the tool systematically and dynamically supports the gradual development of collective knowledge, from the moment of birth of an initial individual idea to its crystallization into artifacts of shared understanding.
Retrospectively, testing the structuration elicitation support offered by the *Ideasticker* on a complex collective task in an electronic educational setting proved to be a difficult endeavor. It did not result in statistically significant and clear-cut answers to our predefined hypotheses. Yet students state that the support tool worked well. And, more important, most users expressed positive expectations of the elicitation instrument tested, with some adaptations and elaborations to support the different stages of knowledge evolution.
From the qualitative data gathered two points for the design of knowledge elicitation support have been emphasized. First any supportive action has to be rather compact for use in daily practice. It should offer a great flexibility to address the changing characteristics of knowledge evolution in virtual team performance. Adult respondents, graduate students and working professionals are especially in need for compact support tools flexible enough to adapt to their teamwork

practice (Bitter-Rijpkema, Jochems & Martens, 2005; Crutzen, 2000). In this respect "less is more": condensed support tools probably optimize knowledge communication better in daily practice than the finer grained support, tested in this experiment.

Secondly supportive action needs to take the dynamics and richness of idea generation processes more serious than the *Ideasticker* did. In this experiment we offered a single format to structure articulation. However, to enhance elicitation to find common ground in function of decision-making and problem solving elicitation triggers are required that recognize the important transitions of individual ideas into collective knowledge artifacts for team performance.

The findings from this experiment and recent literature seem to show that the key issue is not so much a matter of how we offer structuration, but more when, which and how much structuration is relevant at a specific stage of collaborative work. To elicit indispensable insights of team members engaged in knowledge creation for collective team performance requires triggers that seamlessly accommodate to the characteristics of different stages of knowledge evolution.

CHAPTER 5 – Positive effects of knowledge elicitation triggering for virtual team performance[3]

Abstract

Collaborative learning for collective performance is vital in the emerging knowledge-based 21st century economies. Neither effective knowledge creation processes nor excellent team performance occur spontaneously. Hence factors influencing these processes are subject of many research efforts. Our investigations focus on problems of inadequate knowledge articulation and communication of individual input, relevant for team performance. Evidence from earlier studies indicates that socio-cognitive stimuli and dedicated affordances in the virtual workspace might enhance the collaborative knowledge co-construction process.

In this article we present the results of a hypothesis testing controlled trial, assessing the effects of dedicated knowledge elicitation cues combined with enabling functions of the electronic team space. We designed a specific support combination to Augment Collaborative Elicitation (the ACE method). The ACE method consists of cues, suggesting suitable actions, combined with enabling functions of the surrounding workspace. This paper describes the test of the ACE method in a controlled laboratory experiment, involving a two hours virtual teamwork session. We report first results based on analysis of quantitative data. Expert performance ratings did not yet differ significantly. Student's ratings did. In the experimental condition students gave significant higher grades for team performance than their peers in the control condition. The ACE intervention generated also the predicted positive effects with respect to motivation, perceived process quality and knowledge co-construction processes. This paper concludes with interpretation of results and their implications for design and future research.

Introduction

Jessica Lipnack and Jeffrey Stamps (1997) state: "dispersed teams are the peopleware of the 21st Century". Doing knowledge intensive work in a

[3] Bitter-Rijpkema, M. E., Jochems, W. M. L., Martens, R. L., & Berens, H. *Positive effects of knowledge elicitation triggering for virtual team performance*. Manuscript submitted for publication.

distributed team across the organization or globe is rapidly emerging (Allee, 1997; Boisot, 1998; Davenport & Prusak, 1998; Orlikowski, Yates & Fonstad, 2001; Ridderstråle & Nordström 1999; Sveiby, 2001). Progressive economic globalization and rapid technological changes require structural different competencies of professionals today (Simons, van der Linden & Duffy, 2000; Snowden, 2002; Wenger & Snyder, 2000; Yeh, Pearson & Kozmetzky, 2000). Professionals have to collaborate with teammates from different disciplines to produce collective results in time, within rapidly changing organizational contexts.

Complexity of tasks and time constraints necessitate professionals to keep on learning. More than ever initial education only provides the student with start qualifications.

Innovative concepts are explored to prepare students for their professional future. Designers develop educational environments like the "Virtual Business" concept of the Open Universiteit Nederland (Bitter-Rijpkema, Sloep, & Jansen, 2003), immersing students in authentic work practice, offering them authentic experience of professional practice before graduation. Concurrently teachers introduce their students in adequate use of advanced tools in their field of specialization.

After graduation professionals have to keep on learning at work to be able to contribute timely and adequately to solutions for new problems. Yeh (Yeh et al, 2000) refers to this type of lifelong learning at work as "stealth" learning: a quick response type of learning as an invisible part of professional teamwork. A productive type of learning to close the gap between what is known and what needs to be known to timely generate collective results. The question is how to support this type of learning over a professional's lifetime.

Supporting a virtual team's knowledge co construction processes

To state that the professional's learning capacity is the crucial factor at stake is one thing, enhancing their learning process is yet another (Ridderstråle & Nordström, 1999; Conklin, 2003). Scale and efforts of investigations in the domains of collaborative computer supported

work and learning, knowledge management, virtual teamwork and decision support systems underline the importance and urgency felt to find new ways to support professional learning (Snowden, 2002; Brown, Collins & Duguid, 1989; Von Krogh, Ichijo, Nonaka, 2000).
Collaboration on complex ill-structured problems, at the core of professional work, is known to be difficult. (Conklin, 2003; Fischer, Grudin, McCall et al., 2001; Suchman, 1987). Without assistance, professional teams often fail to reach optimal performance (Santanen & De Vreede, 2004). Implicit but incorrect assumptions about one's peers position for instance easily leads to breakdowns.
This study addresses the question whether an intervention explicitly developed to augment collaborative elicitation (further on referred to by its abbreviation *ACE* = Augmentation of Collaborative Elicitation) is capable to enable effective knowledge articulation and exchange, needed for collective performance.
The *ACE* method to enhance articulation and subsequent collective inquiry is built on the following assumptions. Personal knowledge in virtual teamwork emerges in team discourse. (Von Krogh et al., 2000, Suchman, 1987, Fischer, Grudin, McCall et al., 2001). Once implicit personal knowledge is articulated for collective learning or team performance, ideas materialize in tangible artifacts. These articulations vary from ideas written down to design prototypes, proposition for proposals and a variety of other tangible artifacts. Next initial articulations evolve during subsequent discussions. They are commented, modified, rejected or integrated into new propositions.

Experts, consulted in a Delphi study earlier in this project (Bitter-Rijpkema, Martens & Jochems, 2002) and authors like Nonaka (Nonaka & Konno, 1998) and Dillenbourg (2002) discern two ways to facilitate collaborative knowledge development: first indirect facilitation, trying to influence team composition, group size and team task, and second direct facilitation, trying to influence a team's interactions. In our study we focus on the latter, the possibilities of direct facilitation. In prior investigations methods to structure interactions (Dillenbourg, 2002; Fidas, Komis, Tzanavaris & Avouris, 2005; Hmelo-Silver, 2003; Jeong &

Chi, 2000; Plötzner & Fehse, 1998), triggering for systematic explanation (Bitter-Rijpkema et al., 2002; Bitter-Rijpkema, Jochems & Martens, 2005; Chi, De Leeuw, Chiu & LaVancher, 1994), elicitation of underlying arguments and structured visualization (Van Bruggen, Boshuizen & Kirschner, 2003; Weinberger, Fischer, & Mandl, 2001) have been tested. These empirical studies show positive results in controlled settings. However these results have not yet been replicated successfully on ill-structured tasks in fluid open settings, which are typical for workplace learning.

Researchers like Nonaka & Takeuchi (1995), Fischer (Fischer, Grudin, McCall et al., 2001), Crutzen (2000), and evidence from our own research (Bitter-Rijpkema, Martens & Jochems, 2002; Bitter-Rijpkema, Jochems & Martens, 2005) argue that optimal support for knowledge articulation and development should be able to boost and nurture the evolution of initial articulations to mature artifacts.

The *ACE* method tries to prevent breakdowns (Suchman, 1987) and stimulate knowledge emergence (Von Krogh et al., 2000) building on the aforementioned ideas. *ACE* offers a new combination of supportive actions and functions, flexibly enhancing effective knowledge elicitation and subsequent collaborative co-construction of team performance. The *ACE* triggers and supportive functions are designed for autonomous use by the team members as tools "at hand", "ready to use" (Winograd & Flores, 1987) in the "critical interactions" (Crutzen, 2000) of the team. Tangible artifacts surfacing in team interaction are seen as "seeds", able to evolve and open for further re-used and remodeling up to the crystallization point of team result (Fischer, Grudin, McCall et al., 2001).

ACE forum

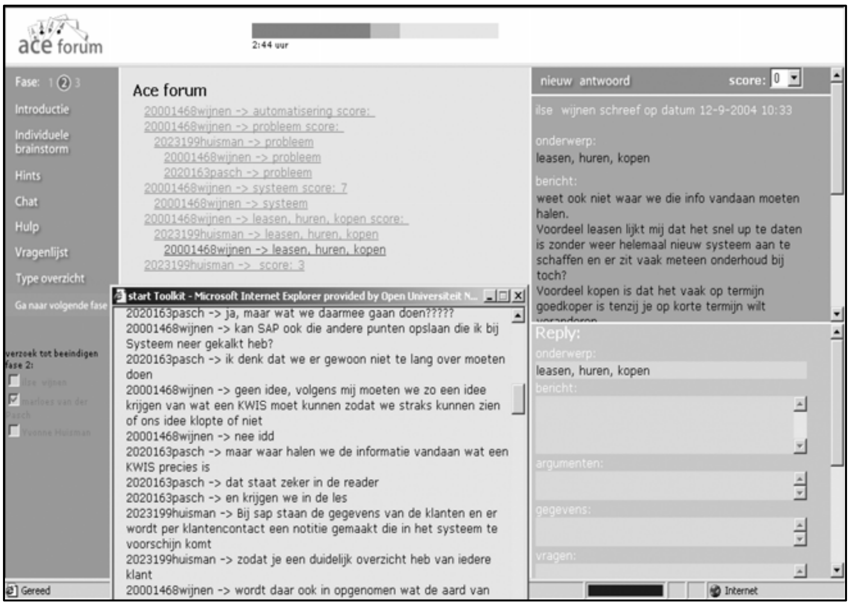
The proposed evolving-artifacts approach to collaborative knowledge elicitation and co-construction has been implemented in a prototypical test environment, called the *ACE forum*[4]. The *ACE* intervention aims to support knowledge elicitation and development for collective performance in two ways. It offers active stimulation via expert's advice

4 Acknowledgement: Mr. W. Slot (OTEC) developed a rapid implementation of the evolving artifact approach in *ACE forum* (scalable for operational use).

and it offers dedicated functions, enabling the necessary evolution of knowledge artifacts. It uses a combination of stimuli (reflection and action advice, presented as hints) and enabling functions (presence indicator of active peer's; mind map and meta-tagging functions; re-use, scoring and voting mechanisms) in the team's workspace.

To get a flavor of the *ACE forum* environment Figure 5.1 gives an overview of the discussion area, with an open chat window for coordinative activities and social talk.

Figure 5.1 Discussion space of ACE forum



Appendix 5.1 shows three other screens: a participant's mindmap as input for the team discussion (1st screenshot), a view of the discussion space (2nd screenshot) and an overview of the report space (3rd screenshot).

In *ACE forum* hints are used to actively stimulate the knowledge articulation and co-construction process. At the same time affordative (Kreijns, 2004) functions of the team space enable team interactions and the dynamic process of evolving knowledge construction. *ACE* supports

the knowledge evolution in all phases, from brainstorming to the final report of a team's advice. For the discussion phase the hints concentrate on problem solving activities, pursuing a deep and systematic inquiry. For the next phase, they are centered on effective composition of the team's solution report.
To prevent information blocking we first advice an individual brainstorm, supported by an electronic mind map (Appendix 5.1 screenshot 1). The mind map can further on be used as a frame of reference. Sharing of individual mind maps into a team map is envisaged, but was not yet implemented since we wouldn't be able to test it within the tight time constraints of this lab setting. During the whole process dedicated hints are offered, suggesting relevant problem solving actions plus methods to ensure effective knowledge communication. Complementary domain specific advice, in our case on Facility Management issues, is given. Users are able to rate these hints as valuable, neutral or of no value to them. Over time *ACE* hints can evolve too based, among others, on this informative user feedback. Discussion itself is supported by specific functions such as chat, to provide a channel for social and coordinative discussions, apart from the content-based problem solving process. A voting mechanism supports the team decision to pass on to the next phase. In the report phase hints offer suggestions for decision-making and presentation of results. Specific functions enable teammates to introduce topics and propose their ideas on optimal sequencing for the team report. And finally a help function is permanent available.
Hints suggest methods to execute individual as well as team reconnaissance of the problem space. They offer advice for a suitable team organization to clearly articulate ideas and to check for comprehension by mirroring ideas back (see Appendix 5.2). Team members are triggered to cluster and organize, both converging and diverging ideas, using the labeling options. The scoring of contributions enables prioritization. Other hints give suggestions for systematic and deep inquiry (Argyris,1993b; Argyris & Schön, 1996; Hipple, 2005). Accompanying hints provoke participants to systematically test solution proposals from different perspectives.

Testing the ACE forum

To investigate whether the *ACE* intervention indeed generates the predicted positive effects tests are needed. In this experiment the *ACE* intervention was tested in a laboratory experiment, offering the opportunity to observe its effects, undisturbed, in a controlled setting.

In this experiment the following hypotheses are tested:

1st hypothesis:
The *ACE* treatment will result in a significant improvement of team performance quality as rated by two independent experts and as perceived by the participants, resulting in higher performance rates in the experimental condition.

2nd hypothesis:
the *ACE* treatment will boost existing motivation, resulting in significant higher scores for post task motivation.

3rd hypothesis:
the *ACE* treatment will generate a more positive perception of the team process in the experimental condition. The improvement of perceived process quality will result in significant higher scores for perceived group openness and trust, experienced team collaboration and team coordination.

4th hypothesis:
the *ACE* treatment will result in an improvement of perceived knowledge building processes and outcomes, as shown in significant higher scores for emerged shared understanding, increase of perceived collective knowledge performance, knowledge sharing and a decreased annoyance with problematic knowledge inquiry.

To test the aforementioned hypotheses we used the following dependent variables. The quality of collective solution as rated by two independent experts and as perceived by the participants. The respondent's motivation, measured via subscales addressing intrinsic motivation, perceived competence and perceived control. The process quality, measured by subscales measuring group openness and trust, shared understanding, and team collaboration and coordination. And knowledge development, measured via subscales assessing teammate's annoyance with the inquiry process, knowledge sharing and performance. All subjects were randomly attributed to conditions. No explicit control variables are used.

Method

The experiment has an experimental-control group design. The independent variable under investigation is the *ACE* intervention. The quality of collective performance, and the appreciation of knowledge co-construction and processes quality are the dependent variables in this study. The *ACE forum* offers hints to support effective knowledge building and expansive inquiry. In addition it offers enabling functions to flexibly organize and reorganize evolving artifacts of participant's articulations. Half of the participants were offered the experimental environment of *ACE forum*. The control group was offered a similar forum with an analog interface but without any of the dedicated *ACE* support functions.

Participants

Participants were students Facility Management of the Hogeschool Zuyd, a Vocational Institute of Higher Education. The *ACE forum* experiment was part of their regular Bachelor's curriculum. For their participation the students received a small symbolic reward (a cd-holder).

The randomized controlled trial was executed twice, as due to a train strike only 24 of the 65 students were able to attend the October 2004 experiment run. With less then 10 teams in each condition (Table 5.1) a new experiment had to be planned for December 2004. We will report results from both runs of this experiment.

Table 5.1 Teams in experimental and control condition

Experiment period	N	Condition	N	Team
Total: October + December 2004	92	Experiment	46	16
		Control	47	17
1st run: October 2004.	24	Experiment	11	4
		Control	14	5
2 nd run December 2004.	68	Experiment	35	12
		Control	33	12

Both groups consisted of Facility Management (FM) students. Group and course settings differed with respect to prior knowledge and motivation. The October group was a 4th, last year group who already had apprenticeship experience. The December group consisted of 2nd year FM students, without apprenticeship experience in their field of study. This might cause some difference in motivation, because, according to their tutors, students' motivation increases substantially once students have completed their apprenticeship.
Groups of FM students are quite heterogeneous. The prior education of the experiment groups differ: from medium level vocational training (MBO), a range of secondary school variants (MAVO, HAVO, VWO) to university study (BA level) (see Table 5.2).

Table 5.2 Prior education of participants

Prior education	October frequency	December frequency
MBO	5	7
MAVO	1	0
HAVO	13	46
VWO	5	14
University	1	1
Total	25	68

For this type of virtual teamwork task we considered 3-4 person teams as the optimal team size for our laboratory test. Train strike and course schedule constraints forced us to form several smaller (2 person) or larger (5 person) teams. Together the October and December group consisted of 41 male and 52 female participants. Sexes were evenly spread in the December group (32 male versus 36 females). Female dominance characterized the October group (9 male versus 16 female). Students were between 18-33 years of age (for the respective runs 20,5 and 21,8 year on average).

Procedure

The experiment consisted of a single session in which a team had to solve a client's case. Participants worked completely virtual as a distributed team. All team communications took place in *ACE forum*. The October and December sessions were organized in the OTEC laboratory.

Blackboard is the respondent's regular electronic learning environment. For them the *ACE forum* was a different new e-learning environment. No prior training was given. Prior to task execution the teams received a short, 7-minute, introduction. The introduction familiarized participants with the nature of the task at hand, the planning of the session and how to use the system. During the experiment session on-line help was available. In case technical problems should arise the designer of *ACE forum* would help out. But apart from some logon problems, related to the recombination of teams, his technical assistance was not needed.

All subjects were randomly attributed to conditions. Numbers were drawn, assigning students to a team-condition combination. Time-on-task was 2 hours in both conditions. An additional hour comprised execution of introduction, pre-survey, individual brainstorm, intermediate and post-task surveys plus administration handling.

Task

In both conditions teams worked as professional, self-regulating teams. The teams worked completely virtual, the entire collaboration took place via computer communication. Members belonging to a team were located in separate rooms. Teams had to analyze the problem and write a concise advice.

Each team received the same type of task. The task at hand was a typical professional task: authentic, complex and ill structured. The instantiation of the client case differed for October and December. For the 2nd year group the Bike Factory case focused on an information management problem. The team task was at the start of their course on FM Information Systems. The 4th year students had to solve a whistleblower's case (see Appendix 5.3), situated late in their Risk Management course period. Thus the 4th year October students had more, recently acquired relevant course knowledge at their disposal then the 2nd year December group.

Materials

ACE forum introduced the aforementioned specific affordances for effective knowledge articulation and co-construction into the virtual collaboration space.

Measurement

General questions addressed student characteristics, team-task attitude, intermediate and post task process and outcome perceptions. To measure the effects of the proposed *ACE* interventions we used a set of 13 scales to measure the four relevant key dimensions for our hypothesis namely, performance, motivation, team processes and knowledge development.
Scales used have been validated earlier, either elsewhere (Bulach, 1993; Saavedra, Early & Van Dyne, 1993; Savicki, Kelley & Lingenfelter, 1996) or in our prior experiments (Bitter-Rijpkema, Martens & Jochems, 2002; Bitter-Rijpkema, Jochems & Martens, 2005). Table 5.3 gives an overview of the scales used, the type of scale and their reliability.

Table 5.3 Overview of scales used

Scales used	Likert scale	Time	Items	N	Cronbach Alpha
Expert performance ratings (Bitter-Rijpkema, 2005)	5	Post	5	2	.93
Student Performance rating (Bitter-Rijpkema, Jochems & Martens, 2005)	10	Pre Post	4 4	66 66	.93 .83
Motivation- intrinsic motivation (Deci, et al.,1994)	7	Pre Post	5 5	91 86	.88 .88
Motivation, perceived competence (Martens & Kirschner, 2004)	7	Pre Post	5 5	91 88	.74 .81
Motivation, perceived control (Martens, Gulikers & Bastiaens, 2004b)	7	Pre Post	5 5	88 91	.22 .81
Collaborative openness and trust scale (Bulach, 1992)	5	Pre Post	6 6	91 61	.86 .91
Shared Understanding (Mulder, 2004)	5	Int Post	10 10	66 84	.89 .85
Perceived team collaboration(Savicki, et al. 1996)	5	Post	7	62	.87
Perceived team co-ordination (task strategy) (Saavedra, et al., 1993, Hackman, 1976)	5	Post	5	62	.85
Knowledge inquiry annoyance scale (Bitter-Rijpkema, Jochems & Martens, 2005; Saavedra, et al., 1993)	5	Post	5	84	.65
Collective knowledge performance (Bitter-Rijpkema, Jochems & Martens, 2005)	5	Post	7	85	.82
Knowledge sharing (Bitter-Rijpkema, Jochems & Martens, 2005)	5	Post	8	85	.89

^Results from pre-task, intermediate (between 1st & 2nd phase) plus post-task surveys

Finally participants were asked for further experiences via open questions.

Collective Performance. For the December run both expert and student performance ratings are at our disposal. Two independent experts, teachers Facility Management at the Hogeschool Zuyd, independently rated team-performance. We measured the agreement between the evaluations of the two raters both rating the 24 team reports, via Cohen's Kappa. The experts rated performance on a five points Likert scale, ranging from 1 for poor quality to 5 excellent. They rated the overall quality of team performance (Cohen's kappa = .56). Furthermore they rated the quality of team performance with respect to originality (Cohen's kappa = .77), argumentation (Cohen's kappa = .55), presentation (Cohen's kappa = .61) and perceived depth of inquiry, knowledge construction. (Cohen's kappa = .56). Students rated collective performance on a 10 points Likert scale at two moments in time, first after the discussion phase and secondly after report completion. A 10 points scale was used, ranging from 1 for poor quality to 10 for excellent quality, since this is the default rating scale at their institute.

Motivation. The motivation scales address three key dimensions of participant's motivation, namely their intrinsic motivation (original Cronbach Alpha .90) their perceived competence (original Cronbach Alpha .74) and perceived control (original Cronbach Alpha .60). The motivation scales combine the Intrinsic Motivation Scale (IMI) of Deci, Eghrari, Patrick & Leone (1994) translated into Dutch with scales tested by Martens & Kirschner (2004a). They provide measurement of intrinsic motivation via questions like "working on this task seems pleasant". The statement "this type of work is in reach of my ability" is typical for the perceived competence section. While the perceived control measure assesses the influence of the individual on the team process via questions as "I expect to be able to influence our team's activities".

Team attitude. Questions like ″I expect that my teammates will have an open attitude towards my contributions ″ and "I fully trust my teammates at the start of our project" are used to investigate a group's openness trust (Bulach, 1993).

Shared Understanding. The shared understanding scale (Mulder, 2004) measures the existence and nature of shared understanding at a specific moment in time. Midway and afterwards respondents are asked whether the team has a shared understanding of their task, goals or necessary activities.

Perceived team collaboration and co-ordination. Based on Savicki et al., (1996) and Saavedra et al., (1993) perceived team collaboration and co-ordination are investigated, using statements as "all team members came forward with suggestions to solve the problem", and "all team members involved each other in decision making".

Annoyance with the knowledge inquiry process. To address the respondent's perception of the knowledge inquiry process we asked whether respondents perceived breakdowns in the collective inquiry process. This scale, developed and tested prior to this experiment, by Bitter-Rijpkema, Jochems & Martens (2005), inquires if respondents had the idea that their team couldn't keep focused, followed sidetracks, etc. In this way we tried to find out whether respondents had the idea that the team followed an effective inquiry strategy. Low scores on the knowledge annoyance scale indicate high satisfaction with the knowledge inquiry strategy. High scores on this scale indicate that the team experienced a troublesome inquiry process.

Knowledge sharing and collective knowledge performance. The knowledge-sharing effectiveness scale of Majchrzak & Malhotra (2004) has inspired the knowledge communication scales of Bitter-Rijpkema, Jochems & Martens (2005). One subscale measures knowledge sharing satisfaction. A separate scale investigates whether subjects think that the team succeeded to integrate their individual ideas into the collective proposition in such a way that one could agree with the proposed solution.

Results

A variety of quantitative (expert ratings and surveys) and qualitative data (open comments and session loggings) have been collected in this experiment. In this section we will report first results for each of the hypothesized effects solely based on the quantitative data gathered.
To test the hypothesized effects we first conducted a MANOVA followed by ANOVA's. For all analyses a significance level of $p < .05$ has been used. In the next section we will report the results for each of our four hypotheses.
The results of the initial MANOVA, using Wilks's lambda, indicate significant differences (p-value = .011) between the experimental and control condition. Control on the pretest scales didn't show significant differences between the groups. The initial motivation for example didn't differ significantly, as can be concluded for the pretest results for the motivation scales as shown in Table 5.4. Note by the way, that the October and December group differ, as stated earlier, with respect to the motivation level. In line with the teacher's expectation, motivation scores of the 4^{th} year October group are higher than those of the 2^{nd} year December group.

Table 5.4 Pre-test results for motivation

		Experiment		Control		
Pre-task attitudes	Period	M	SD	M	SD	*p*-value
Pre-task intrinsic motivation	Total	4.23	0.97	4.20	1.25	.43
	October	4.90	1.19	4.52	1.11	.36
	December	4.01	0.79	4.06	1.30	.33
Pre-task perceived competence	Total	4.97	0.78	4.92	0.84	.19
	October	5.52	0.80	4.91	0.97	.10
	December	4.80	0.69	4.92	0.78	.49
Pre-task perceived control	Total	4.70	0.50	4.59	0.63	.43
	October	4.33	0.27	4.20	0.42	.36
	December	4.82	0.49	4.76	0.64	.63

* < .05 ** < .01

N=85 for Oct + Dec, N=24 for Oct and N=61 for Dec

Follow-up ANOVA's were conducted to investigate the precise results for each of the dependent variables.

Performance improvement

In the first hypothesis we predicted a significant higher quality of team performance for the experimental condition. Hence expert and student ratings should show significant higher grades for the experimental *ACE* condition. Two independent experts only rated performance for the December teams. Extreme low attendance at the October session, caused by the train strike, necessitated us to run a new experiment. At that time no raters were available for the October session and all resources were needed to swiftly organize the December run. The raters assessed overall performance as well as specific performance aspects. These ratings don't demonstrate significant differences, as can be seen in Table 5.5.

Table 5.5 Expert ratings of performance

		Experiment		Control	
Scale (expert ratings)*	Period	M	SD	M	SD
Overall performance (total score)	December	3.04	0.94	2.79	1.30
Originality of team performance	December	2.96	1.17	2.83	1.45
Argumentative quality of performance	December	2.67	1.03	2.42	1.27
Presentation quality of performance	December	3.46	0.96	2.71	1.27
Depth of inquiry	December	2.37	1.17	2.54	1.17

Oct 2004: no expert rating available

Dec 2004: treatment N=12 teams, no treatment N =12 teams

*Expert scales consist of 5-point Likert scale items

Student performance ratings are summarized in Table 5.6.

Table 5.6 Student ratings of performance

		Experiment		Control		
scale (student ratings)	Period	M	SD	M	SD	*p*-value
Student intermediate rating	Total	6.85	1.55	5.64	2.21	.03*
	October	6.90	1.63	6.11	2.20	.04*
	December	6.84	1.55	5.38	2.22	.01*
Student post task rating	Total	7.15	1.17	5.98	1.92	.01*
	October	7.40	1.00	7.36	0.76	.90
	December	7.07	1.22	5.33	1.97	<.01**

* < .05 ** < .01

N= 68 or intermediate rating, consists of N=19 for Oct and N=49 for Dec

N=85 for Oct +Dec, consists of N=24 for Oct and N=61 for Dec

Note: Student rating scales consists of 10 point Likert scale items

The ANOVA analysis of student ratings at the end of the discussion phase produces significant higher scores for the experimental condition. (p-value = .03). The results of the December group alone are significant too (p-value = .01). The October results alone are not significant. Student post task scores show identical results.

For both runs together students in the treatment condition rate their performance significantly higher than students in the control condition (p-value = .01). For the December experiment alone results are significant (p-value < . 01) too.

After we transpose the expert ratings to a 10-point scale comparison shows that the student ratings for team performance are slightly higher for the experimental condition. Students rate final performance for the *ACE* condition with a Mean of 7.07, (SD 1.22) while expert's rates are Mean 6.08 (SD 1.88). Team performance in the control condition is rated lower by students with a Mean of 5.33 (SD 1.97) than the experts with a Mean of 5.58 (SD 2.60). However, these differences are not significant.

Motivation

The second hypothesis predicts significant motivational effects, with respect to intrinsic motivation, perceived competence and control.

Table 5.7 Intrinsic motivation scores

		Treatment		Control		
scale	period	M	SD	M	SD	*p*-value
Post-task	Total	4.41	1.19	3.95	1.39	.10
intrinsic	October	5.14	1.06	4.78	1.47	.50
motivation	December	4.15	1.13	3.56	1.19	.05*

* < .05

N=85 for Oct + Dec., N=24 for Oct and N=61 for Dec.

Results of the ANOVA analysis are presented in Table 5.7. A significant higher post task intrinsic motivation is observed for the experimental condition in the December run (p-value = .05).

Post-task ANOVA results for perceived competence, depicted in Table 5.8, show a significant difference between treatment and control condition (p-value = .03). The effect for post task perceived competence of the December run alone is even stronger (p-value < .01).

Table 5.8 Perceived competence scores

		Treatment		Control		
scale	period	M	SD	M	SD	*p*-value
Post-task	Total	5.15	0.73	4.67	1.16	.03*
perceived	October	5.56	0.74	5.14	1.51	.40
competence	December	5.02	0.69	4.46	0.91	<.01**

* < .05 ** < .01

N=85 for Oct +Dec., N=24 for Oct and N=61 for Dec.

Scores with respect to post task perceived control for both runs are shown in Table 5.9. Significantly higher scores are observed for the overall experimental condition (p-value = .02), and for the December run alone (p-value = .01).

Table 5.9 Perceived control scores

		Treatment		Control		
scale	period	M	SD	M	SD	*p*-value
Post-task perceived control	Total	5.08	0.72	4.67	0.82	.02*
	October	5.45	0.74	4.96	0.89	.21
	December	5.00	0.70	4.54	0.77	<.01**

* < .05 ** < .01

N=85 for Oct + Dec., N=24 for Oct and N=61 for Dec.

Process quality

In our 3rd hypothesis we predict a more positive perception of team process quality in the experimental condition. Due to a technical breakdown in the October run the Likert scale questions on process quality are not available for the October respondents. Quantitative results are only available for December. Significantly higher scores are expected on perceived group openness and trust, experienced team collaboration and team coordination for teams working in the *ACE* treatment condition.

In Table 5.10 we find for the December run significant differences for post task perceived openness and trust (p-value < .01), perceived quality of team collaboration (p-value < .01) and team-coordination. (p-value = .01) indicating that the perceived process quality was significantly higher for the experiment condition as compared to the control condition.

Table 5.10 Process quality indicators

		Experiment		Control		
scale	Period	M	SD	M	SD	*p*-value
Post-task group openness and trust.	December	4.01	0,54	3,53	0,71	< .01**
Post-task team collaboration	December	4,09	0,54	3,39	0,74	< .01**
Post-task team coordination	December	3.92	0,65	3,48	0,70	< .01**

* < .05 ** < .01

N=61 for Dec.

Knowledge development processes

The 4th hypothesis predicts a more positive reception of knowledge co-construction processes, due to the *ACE* treatment. *ACE* supportive actions and functions are expected to result in significant higher scores for shared understanding, knowledge sharing and knowledge performance and lower scores for knowledge annoyance.

Table 5.11 Knowledge building indicators

		Treatment		Control		
scale	period	M	SD	M	SD	*p*-value
Intermediate shared understanding	Total	3.71	0.47	3.16	0.90	.02*
	October	3.75	0.48	3.47	0.48	.27
	December	3.70	0.48	3.04	1.01	<.01**
Post-task shared understanding	Total	3.50	0.35	3.13	0.65	.01**
	October	3.44	0.37	3.44	0.41	.76
	December	3.53	0.35	3.00	0.69	<.01**
Post-task knowledge annoyance	Total	2.48	0.62	2.80	0.57	<.01**
	October	2.16	0.62	2.61	0.49	.06
	December	2.58	0.60	2.89	0.59	.04*
Post-task collective knowledge performance	Total	4.00	0.61	3.37	0.64	<.01**
	October	4.18	0.56	3.63	0.49	.02*
	December	3.94	0.67	3.28	0.67	<.01**
Post-task knowledge sharing	Total	3.86	0.42	3.41	0.70	<.01**
	October	4.07	0.53	3.86	0.48	.31
	December	3.79	0.36	3.21	0.69	<.01**

* < .05 ** < .01

N=85 for Oct + Dec, N=24 for Oct and N=61 for Dec.

Scores presented in Table 5.11 show that students in the experimental condition scored significantly higher on intermediate shared understanding (with a p-value < .02 for the two experiment runs together and a p-value < .01 for December). Measurement of post task shared understanding is significant for the overall (p-value = .01) and December run (p-value < .01).

The knowledge annoyance scale measures barriers experienced for an efficient systematic and deep inquiry strategy. Respondents in the experimental condition show significantly lower (p-value < .01) scores

for knowledge annoyance. This indicates that students in the experimental condition perceived their inquiry process more positive than students in the control group. For the December run a significant difference is observed too (p-value < .05).
The same pattern occurs when we look at the results for collective knowledge performance. We observe significant scores for the experimental condition (p-value < .01) compared to the control condition for both runs together, for the December run separately (p-value < .01) as well as for the October run separately (p-value = .02).
The experimental condition receives significant higher scores for knowledge sharing than the control condition, for both experiments together (p-value .01) and for the December experiment apart (p-value < .01).

Discussion

In this study, dedicated support for knowledge elicitation and its progressive evolution towards collective team knowledge construction, was put to a first test in a controlled laboratory setting. Expert hints and supportive functions were embedded in the collaborative *ACE forum*. This study aimed to investigate whether predicted effects on respective performance (H1), motivation (H2), process perception (H3) and knowledge development (H4) dimensions would occur.
The primary point of interest of educational design efforts is whether it improves the end result, the quality of performance. Therefore we gathered performance ratings of both experts and students. We observed that student ratings of overall performance, both halfway, after the discussion phase, and after task completion show significant support in favor of the *ACE* intervention. The *ACE forum* users perceive a higher quality of performance for the discussion as well as the report phase, than their peer students in the control condition. This demonstrates that even after a short period of use the treatment influences performance as perceived by the students. So the first effect is a positive effect on the subjective performance perception of participants.

But expert ratings are a better measure of performance, assessing performance quality according to more objective criteria. The expert ratings in this study don't yet result in significant evidence in support of the hypothesized expert rated performance improvement. This observation is in line with several other experiments in the field of computer supported collaborative work and learning (CSCW/CSCL). In many CSCW/CSCL studies process improvements are observed (Mulder, 2004; Strijbos, 2004; Weinberger, Fischer & Mandl, 2001) but clear-cut evidence for significant, expert rated, performance improvements are not yet found. We have to ask ourselves whether we have been too optimistic to expect expert benchmarked performance results of our intervention, addressing complex activities as team collaboration in cyberspace within a single 2 hours session. Suggestions are that repeated use over longer periods of time is needed to find effects on collective performance. In the limited timeframe of our lab setting, regular course students had get used to new teammates, a new environment and they had to solve a challenging complex task. It is important to notice that the teams managed to come to the requested collective performance. At the same time a higher level of performance quality is reported in the *ACE* condition compared to the control group. Further research is needed to find hard evidence of expert benchmarked performance improvement. Repeated use over a longer period, in a field-test, should assure team members enough opportunity to get accustomed to and value all sophisticated support options offered. We expect that once *ACE* facilities have a chance to become part of a team's work practice repertoire the strength of the intervention will significantly effect the expert rated performance quality.
To this point *ACE* has already led to the subjective perception of students that they produce results of higher quality. Future research has to prove whether *ACE* support is able to survive in daily practice and sort the predicted, expert rated, performance effects.
Regarding the other hypotheses, this experiment already resulted in the predicted improvement on motivation, process quality and knowledge development. On these dimensions a recurrent pattern emerged. We reported significant results for the experimental condition for the two

runs together and for the December run alone. The results of the October run most of the time are in itself not significant. We assume that this is primarily due to the small sample size. In addition we were forced to recombine students into often too small (2 person) teams. This might have introduced additional disturbances. Besides, as stated earlier, there existed differences in experience and motivation between the students of the first and second run.

Nevertheless within 2 hours of intensive use the *ACE* treatment resulted, overall and for December alone, in significant effects. For motivation the treatment condition stimulated a significant increase in intrinsic motivation, perceived competence and perceived control as predicted. The *ACE* approach, not imposing a prescribed procedure but giving advice on suitable actions, seems to motivate its users. They feel more competent to meet virtual team-task requirements, and more in control. A quick scan of qualitative comments on *ACE forum* affirm these observations. *ACE* improves motivation on all key elements of motivation. This observation is very important since enjoyment, and motivation are vital for successful learning and sustainable use of support tools. Motivation is assumed to ignite active participation and nurture other processes (including trust building) critical for collaborative knowledge building and learning (Martens, Gulikers & Bastiaens, 2004b).

Research on fruitful collaborative knowledge building suggests that openness and trust are important predictors for successful collaborative knowledge development and team performance (Fidas, Komis, Tzanavaris & Avouris, 2005; Hmelo-Silver, 2003; Nonaka & Konno, 1998). We envisaged that users of *ACE* would be more open and have more confidence in their peers, due to the improved understanding of peer contributions in the *ACE* setting. Besides we presumed that both the hints, suggesting suitable actions for systematic articulation and comprehension, in combination with the dynamic structuration functions, to arrange and reorganize articulation artifacts in the workspace, would produce a predictable, positive climate for teamwork and learning. Process quality scores indeed indicate that the *ACE* combination of hints and enabling functions enhance an improved climate of interpersonal openness and trust compared to the traditional environment as mimicked in the control condition.

Reports on breakdowns in distributed teamwork are ample. Teams often have problems to keep focused. They proceed inefficiently and sometimes ineffectively towards the team result. Hence sometimes individual team members have the feeling that dead ends were explored for too long. In this experiment however teams in the experimental condition were more positive about their inquiry strategy, than those in the control condition.

Responses on knowledge sharing and knowledge performance scales indicate that in the *ACE* situation relevant individual insights are better taken into account. Scores for systematic solution search and critical investigation are substantially higher than predicted in the fourth hypothesis. Furthermore subjects indicate that, from the discussion phase onwards, teams experience more shared understanding than their peers in the control condition. Observations regarding collective knowledge performance indicate that in the *ACE* condition team members experience a more balanced and effective integration of their insights into collective team knowledge. And finally, *ACE* treatment, as predicted, did positively influence knowledge sharing activities.

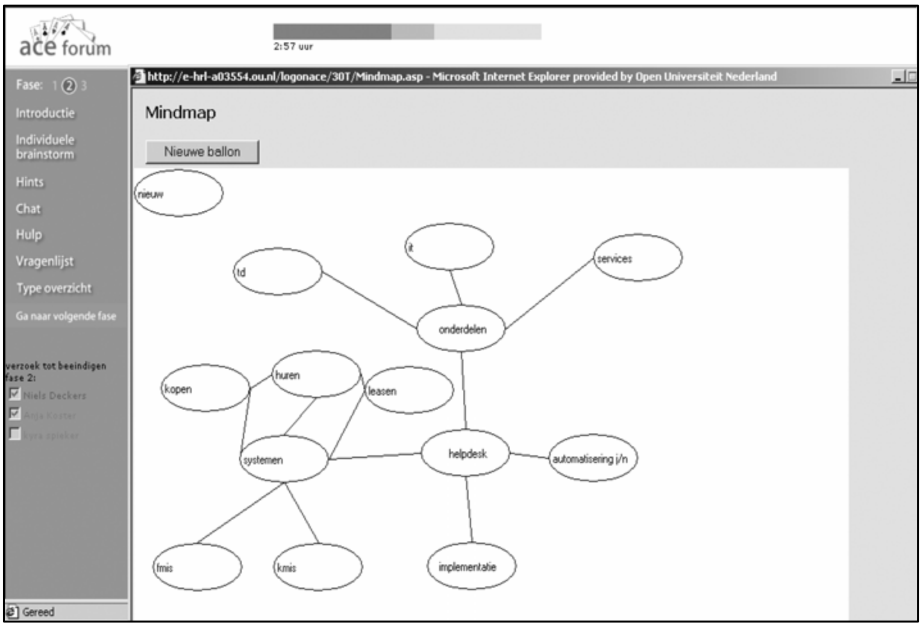
In conclusion *ACE* hints and dynamic structure options of *ACE forum* sorted the predicted effects with respect to an improved perceived quality of collaborative knowledge performance and knowledge co-construction processes as predicted in the 1st hypothesis. A substantial increase in motivation, process quality and knowledge development has been observed as predicted in the 2nd to 4th hypothesis.

The results found in this laboratory test can be explained by the fact that *ACE* provokes and nurtures from the start onwards the emergence of a collective frame of meaning and thus a shared reference. Our first results of combined activation to trigger knowledge articulation and support the subsequent evolution of articulations to the emergent team knowledge constructs are in line with what we expected. It is the specific combination of elicitation support methods that generates this effect. We implemented multiple methods to articulate one's ideas, based on Nancy Cooke (Cooke, 1999; Gorman, Cooke & Kiekel, 2004) findings that differential elicitation methods tap into different types of knowledge. We developed evolving support, enabling team members to build, merge, reuse, reorganize and elaborate on existing articulations, since Stahl (2000a) and Fischer (Fischer, Grudin, McCall et al., 2001) demonstrated how individual contributions gradually evolve and merge into the collective knowledge construct. From this we learned that the supportive action had to match diverse articulations formats and had to follow the further evolution of initial articulations towards the crystallized artifacts that constitute the team result.

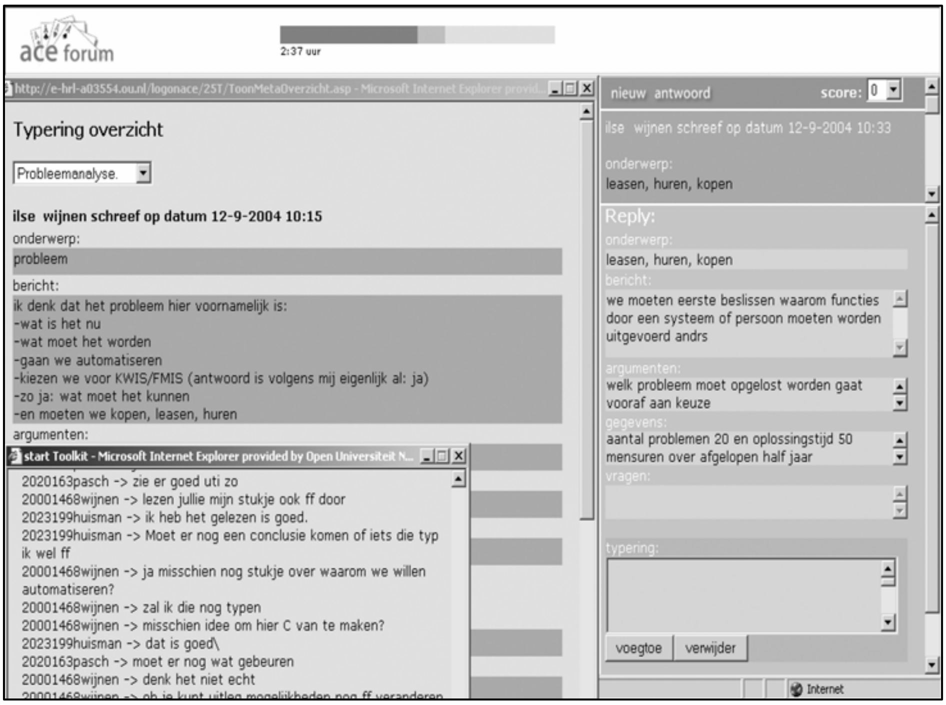
Further analysis of qualitative data has to give us insight into the nature and evolution of team knowledge co-construction under *ACE* circumstances. Future research too has to indicate if and under what conditions expert benchmarked performance results occur, directly caused by the *ACE* treatment. After this proof of concept, further field-tests with larger samples of representative teams of both working professionals and graduate students need to substantiate the effects that application of the *ACE* method can sort in natural circumstances. After initial small scale tests in the laboratory the ultimate challenge is to prove that the proposed *ACE* interventions are robust enough to be effective during regular use in daily educational and professional practice.

Appendix

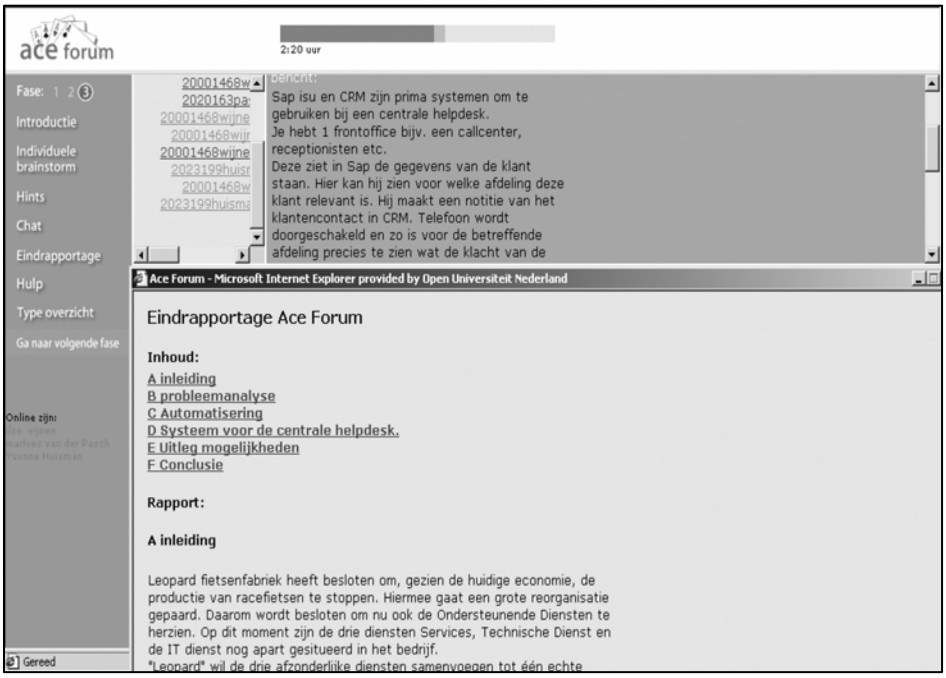
Appendix 5.1.1 Screenshot ACE forum of individual brainstorming mind map



Appendix 5.1.2 Screenshot ACE discussion space with chat and labeled output



Appendix 5.1.3 Screenshot Overview of ACE forum report space



Appendix 5.2 Example of elicitation hints in ACE forum

 Exchange Check & Clarify.	Give each idea a fair change. React, check and complete the ideas of your peers: mirror your interpretation. Checklist: • Articulate your ideas as clear as possible. • Underpin your idea with arguments, data and evidence. • Define what you know, you don't know yet, or need to know. • Read all messages of your peers. • Don't judge. Don't condemn ideas. • Test your comprehension of each idea. • Mirror your interpretation by asking open questions. • Answer all questions on your contributions. • Summarize the ideas of your discussion threads. Note and cluster shared perspectives. Also note: different perspectives. *Enablers*: structure fields, meta-tagging options, synthesis messages, chat.

Appendix 5.3 The whistleblower case (October 2004)

"BB" poolcenter is housed in an old building. It has only a small stockroom: a long corridor at the rear side of the building. This corridor is used as storage space and escape route: a situation violating existing fire safety rules. "BB" management hesitates what to do. She faces a dilemma, investing in a new stockroom or continue to use the corridor. Considering pro's and con's, the board of "BB" conveniently decides to continue the existing situation. One of the employees however protests. "BB"s manager tells him not to criticize and keep silent. Talking to a journalist the employee points out the abuse at "BB". The 'board hears by rumor of the forthcoming publication. Your team is asked to advice how to handle the actual problem and prevent similar problems in future".

CHAPTER 6 – Discussion and concluding thoughts

"Action springs not from thought, but from a readiness for responsibility"
Dietrich Bonhoeffer (1906-1945)

In the context of fierce global economic competition enterprises have to restrict to increasingly lean constructions. What remains is the employee's motivation, prior knowledge and ongoing learning capability as key differentiator for competitive advantage (Bitter-Rijpkema, Sloep & Jansen 2003; Ridderstråle & Nordström, 1999; Victor & Boynton, 1998).

The prospect of rapid and disruptive changes poses two major learning challenges. The first challenge is to develop advantageous methods to prepare students for their careers as knowledge workers. The second is to design methods to support and advance lifelong workplace learning of professionals, concurrent with their performance activities.

In this thesis we explored new methods to enhance collaborative knowledge articulation in function of distributed teamwork. Aside of scientific interest, the knowledge needs of both working practitioners and students triggered our quest.

Within the context of professional knowledge productivity this thesis dealt with the question how to enhance flexible articulation and integration of individual insights into collaborative knowledge for excellent team performance. How does a professional cope with ongoing changes in focus, content and context of his work? What support does enhance a professional's capability for excellent performance?

Our attention focused specifically on collaborative knowledge generation for problem types, typical for advanced professional practice, where explorations of new solutions to ill-defined complex problems require multidisciplinary teamwork (Brown & Duguid, 2000; Cook & Brown, 1999). To solve these new, non-routine problems, support should enable maximal use of existing experience and expansive inquiry. Given the fact that each team member's knowledge is crucial for a team's learning and performing at work, we focused on agile methods to improve knowledge articulation and communication.

In this final chapter we draw up the balance. With hindsight we make up our mind and reflect on results so far. In the next paragraphs we address relevance, scope of our research, methods used and results achieved. Based on the results so far we tentatively formulate practical guidelines for educational and professional practice. Next we discuss limitations of our research. Finally we conclude with suggestions for future research.

Intensified quest for knowledge

With his statement "we want to share knowledge even with competitors" Rick Harwig (Obbink, 2005), head of Philips Research, illustrates the acute need of knowledge sharing within and across the boundaries of individual workers, projects and organizations. It is a remarkable sign of the continuing relevance of the subject of study of this thesis. Employees are supposed to actively engage in the quest for information and ideas crossing the traditional boundaries of the firm and its partners. Indicative is the increased number of academic and business initiatives on collaborative learning, organizational learning, knowledge management and knowledge communities. The quest to find new ways to accelerate work based learning gets even a sense of urgency, due to the rapid dissemination of new technological changes, the emergence of smart virtual organizations (Wagner, Botterman, Feijen et al., 2004) and the rapid manifestation of new competitors in the global economy. New business concepts demonstrate the same trend. Universities explore the possibilities of collaborative knowledge network models for research and education. Further "industrialization of university education" stimulates propositions of co-makership and mass individualization of learning (Van Asseldonk & Mulder, 2004; Koper & Sloep, 2002).

Another impetus in the Netherlands comes from the government's translation of the need to prepare for the knowledge society into educational strategies and memoranda like e-Learning (Dutch Ministry of Education, 2005a) and Life Long Learning (Dutch Ministry of Education, 2005b).

Aside of the awareness that knowledge productivity is an important business issue, there is a persistent scientific interest in computer supported collaborative learning. Situated learning in collaborative settings is also scientifically strongly promoted as the preferred option (Lave & Wenger, 1991; Lethinen, Hakkarainen, Lipponen, et al., 1999, Von Krogh, Ichijo & Nonaka, 2000). In educational sciences, the idea that knowledge building is intrinsically a social construction process (Jonassen, Mayes & McAleese, 1993; Fischer & Ostwald, 2002; Hakkarainen, Lipponen, & Järvelä, 2002; Stahl, 2000a) gained extensive support, resulting in a growing number of collaboration projects in higher education (Ogg et al., 2004; Bereiter & Scardamalia, 1996).
Examples of new educational formats for adequate collaborative knowledge development can be found at the Open University of the Netherlands (OUNL). The Virtual Master Class project combines student training in scientific publishing on environment and sustainability issues, with collaborative work towards publishing in an e-journal. European wide institutes of higher education participate in the European Virtual Seminar[1]. International, multidisciplinary student teams work for four months on a case related to the enlargement of the European Union and sustainable development. Team members from different European universities work completely virtual to prepare a policy summary. In two Virtual Business (VB) projects collaborative knowledge building is part of real-life professional practice (Bitter-Rijpkema & Crutzen, 2002). In OTO[2], the Informatics Design Company, or the VMAB, the Virtual Business Consultancy firm on Sustainability, computer mediated teamwork and learning are completely intertwined as can be seen from the learn-work concept of the OTO Virtual Business learning project, presented in Figure 1.1 of chapter 1. In line with

[1] At http://goodpractices.surf.nl/gp/goodpractices/157, the European Virtual Seminar project is described as a good educational practice.
[2] OTO Virtual Business Learning firm http://www.open.ou.nl//otonet/

emerging work practices these projects try to effectively integrate collaborative knowledge building into participative professional practice.

Review of results

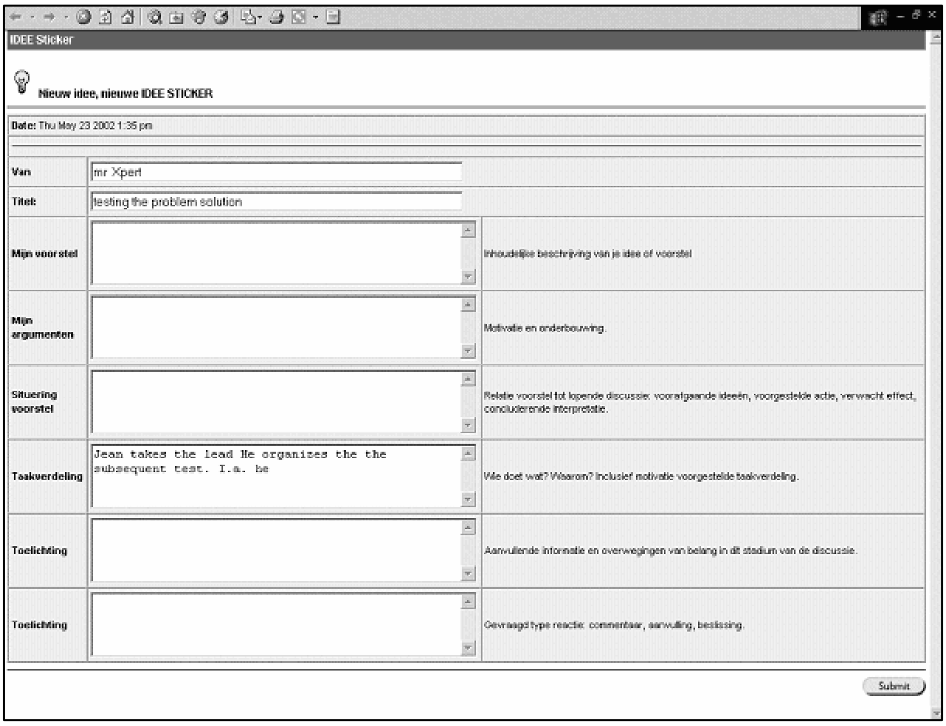
This study limited itself to settings of virtual teamwork, and focused on the computer-mediated part of it. To define the problem space and explore results of prior research, we conducted a literature review on learning and knowledge development in these types of settings.

Chapter 1 offered an introduction into the research subject and proposed a line of research. We observed that ongoing technological, economical and organizational changes heightened attention for work based team learning. We stipulated that a number of issues in the epistemological debate on the precise nature of collaborative knowledge building is still inconclusive. For our aim to develop practical support for professional practices, we decided to pragmatically define "collaborative knowledge building" as a collaborative situated construction process. Furthermore we stated that individual thoughts, once elicited, materialize in tangible representations (texts, video, figures, etc). Effective support for collaborative knowledge building in virtual teams requires that manipulations on these artifacts adequately cope with the dynamical evolution of ideas as they evolve to collective knowledge constructs.

Chapter 2 presented the results of the Delphi study. Since literature alone provided only a limited view we carried out two additional activities. First a Delphi study was set up to elicit expert views. Secondly a survey has been conducted to surface user preferences. The Delphi summarized ideas of representative experts from academia and industry. The qualitative, open format of the Delphi study was chosen to capture the richness of the experts' input. Neutral transmittance of all nuances was ensured via prudent, neutral facilitation. In this way the study delivered indeed remarkable additional information. First experts insist on very frequent prompts for reflection, triggers for expansive inquiry plus enhancement of team member's commitment to the collective cause. New in comparison to available literature was the suggestion to shift from primarily content driven prompting to prompts triggering process and context variables. Experts offered as specific suggestions to trigger ongoing team commitment and monitor the state of shared understanding and performance progress. Finally experts emphasized that only support with a perceived added value for the user will succeed. The expert's perspectives surfaced in this chapter made us aware of relevant dimensions for prompting. Further explorations had to reveal the practical implications for design.

Chapter 3 reports how we explored user expectations. Based on the aforementioned insights a prototypical elicitation-prompting tool, the *Ideasticker*, has been designed. The tool combined triggers for content articulation and triggers to structure process aspects. The "*Ideasticker*", was inserted in the respective workspaces of the student teams in the tests. The *Ideasticker* functioned like a "Post-It"note. Figure 6.1 shows an opened version of the *Ideasticker* in a Blackboard workspace. In chapter 4 one of the other flavours, the Snitzforum implementation, was presented.

Figure 6.1 Blackboard version of Ideasticker



The tool supported systematic elicitation of ideas via a simple text-based template, prompting to articulate core concepts, underlying arguments and result perspective.

Since in real life multi-disciplinary multi-expertise teams are common and Delphi experts suggested that team characteristics require special attention, we additionally explored the influence of differences in expertise on elicitation requirements. The question was whether user's expertness, necessitates a customized tool format. We assumed system activated declarative support as preferred option for novices and post task user activated strategic support as suitable option for proficient users. In contrast to our expectations, all respondents articulated similar preferences. Users prefer self-activation both for the domain of their expertness as well as for new domains. The results of this study didn't provide evidence for the assumption that proficiency of the team members is crucial to the mode of elicitation support. Since this study only was based on a small number of participants (N = 19), its findings need to be reconfirmed by other investigations with substantially more participants. Further investigation on expertness in relation to elicitation might surface evidence to explain the outcomes we found in this study. With the focus of our project on elicitation we decided to continue without specific differentiation for expertise.

Chapter 4 reported user experiences with an improved version of the *Ideasticker*. The second version of the *Ideasticker* tried to enhance articulation, using open fields for initial ideas and social talk, in combination with separate fields for presentation of underlying rationale and prospective expectations.
Twenty-two adult social science graduates of the OUNL tested this version of the *Ideasticker*. Participants worked in teams of 4 to 6 persons on a complex design task and presented a collective proposal. Via logging and surveys we investigated the use and reception of the *Ideasticker*. Teams started without elicitation support. *Ideasticker* support was introduced in the second half of the project. Respondents, in general, were positive about this type of elicitation support and its potential. The within-subject test didn't sort statistically significant effects of the treatment on dependent variables like knowledge communication, collaborative openness or trust. Possibly these results were influenced by the small sample size, the short period of use and the fact that the final phase of the course offered unfavourable conditions for support used. The qualitative output drew our attention to substantial changes in user's structuration needs over time during collaborative problem solving. These ideas together with further literature study inspired the design of a new, alternative elicitation support method. This new method recognizes the changing elicitation needs per phase of knowledge co-construction.

In *chapter 5* we conveyed the results of the laboratory test of this new instrument, a scenario for Augmentation of Collaborative Elicitation, from now on abbreviated as *ACE scenario*. Based on empirical findings from the *Ideasticker* test, the *ACE* stimulation scenario recognizes that the nature of articulations shifts from vague initial thoughts to well-defined expressions of thought. Adequate articulation support has to accommodate for these transitions of knowledge. A ready made standardized elicitation format for the whole problem solving cycle will harness the natural knowledge development process. Hence we explicitly applied Oswald's (1995) "evolving artifacts" ideas in our design of *ACE* knowledge elicitation functionalities.

The underlying assumption is that initial articulations of ideas can be considered as artifacts. These artifacts evolve over time: initial textual or graphical seeds of ideas are enriched with interpretations, elaborations, and plans for action. Later in the debate they crystallize into "collective" artifacts. As advised by our Delphi experts and by findings from usability research, elicitation support has to be "ready to use" and tailorable to the needs of the team and its context. (Fischer & Ostwald, 2002; Crutzen, 2000). Furthermore experts stressed that any support should provide perceivable value added to a no support situation. The *ACE scenario* adds value via suggestions for optimal actions. It doesn't prescribe or impose these, it merely suggests. It presents adequate handling options and suggests use of available enabling functions. The deliberate expansive actions to stimulate further reflection and inquiry are based on the "reflection in action" concepts of Schön (1983) and the model of expansive inquiry inspired by Engeström (2001) Scardamalia & Bereiter (1996) and Snowden (2002). We designed specific triggers to stimulate the team to expand its collective inquiry and explore innovative solutions for ill-defined problems. We applied Argyris (1993b) method of "double loop learning" to widen the horizon of problem reflection, taking also possible fundamental changes in the organizational context into account. Secondly we offered TRIZ based suggestions. Based on Altshuller's TRIZ method of systematic innovative problem solving, applicable suggestions to find innovative solutions are suggested, assessing contradictory perspectives, looking for analogue solutions and applying methods to stretch the initial solutions found to its limits. (Zlotin, Zusman, Kaplan et al., 1999). Examples are illustrated in Appendix 6.1.

The *ACE scenario* brings together ideas from four communities. The community of computer supported collaborative learning, participatory systems design, organizational inquiry and innovative problem solving. With the integration of these ideas into the scenario we have tried to take the design of elicitation support for virtual teamwork a step further.

This chapter reported results of a controlled laboratory test, which studied effects of the new *ACE scenario*. The improved elicitation support consisted of a combination of active interventions on one hand and affording functions in the workspace on the other hand. Active stimuli comprise suitable expert advice. Hints suggest possible actions to expand inquiry at a specific stage and proposed extended reflection for the co-construction of an optimal solution. Additional advice triggered further inquiry from different perspectives using the techniques of Argyris "double loop learning" and Altshuller's TRIZ method. Concurrently we alerted team members to relevant interactive manipulations available in their workspace, to enrich the initial articulations. Both expert advice and enabling functions differ from phase to phase. Functionalities to alternatively express ideas, reorganize, vote, and meta-tag contributions are relevant in the problem analysis phase, while support for outline organization and effective coordination are relevant in the final phase to present the collective solution. The experiment tested how teams of 3-4 persons came to a collective business proposal on a difficult management problem. Half of the teams were randomly assigned to a workspace without any support the others were offered the *ACE* elicitation support. Analysis of quantitative data showed that the treatment sorted predicted improvements as to the participant's own performance ratings, their motivation, perceived quality of team processes and knowledge processes. Expert rates for team performance didn't yet sort significant differences between the two conditions. Albeit to this point positive effects of the *ACE* method to flexible stimulate knowledge elicitation are encouraging. Quantitative positive perceptions are supported by the qualitative comments of participants. On the whole we have to realize that the results of this experiment stem not from the natural learn at work practices. Even though we tried to mimic the natural situation as much as possible and used an authentic problem as part of the participant's regular course, the experiment was a controlled one. We choose for this option to control the situation, prevent disturbing noise and be able to focus on the effects of the *ACE* intervention. The drawback is that this setting imposed several constraints. Due to the fixed formats of regular courses and the number of students enrolled, only a single session exposure of two hours was possible, with a statistically speaking limited number of teams. In line with observations of other laboratory experiments in collaborative learning it is questionable whether this period is long enough for users to get accustomed to the tool, and long enough to observe true representative effects. Even so within these constrained conditions, the *ACE* intervention was positively received and sorted positive effects.

Limitations of research

This project aimed at the design of new elicitation support for collaborative knowledge elicitation in virtual team settings. Empirical tests offered insight into the potential of flexible knowledge building support. The first findings are encouraging. Instruments proved to be useable and attractive. They functioned as expected.

A first limitation lies in our choice to use of existing theories. Multiple theoretical frameworks and fierce theoretical debates illustrate that many fundamental questions still exist. (Burkhardt & Schoenfeld, 2003; Hakkarainen et al., 2002; Haythornthwaite, Lunsford, Kazmer et al., 2003; Hmelo-Silver, 2003; Stahl, 2000a; Tuomi, 1999; Von Krogh, et al., 2000). The development of a consistent theoretical base is still under construction. We have to cope with the dynamics of the debate and the theories in use in this field. Our attention focused on the elicitation aspect, which is only one component within the complex cluster of learning, knowing and knowledge in collaborative performance.

Theoretically we looked for frames of reference well suited to the interpretation of elicitation processes. Hence we need to realize that our investigations inherit the limitations of the theories it uses.
Secondly, the small sample size in this study limited applicable experimentation methods. Especially since we looked for results at team level the small number of students is an extra hindrance, restricting available experimentation options once more. A well-known problem with this type of educational studies is the fact that often only small number of groups can be gathered for testing. It proves difficult to find large test groups with the required team and task characteristics, available for longer periods of time and repeated measurement. (Burkhardt, 2005).
Thirdly, testing interventions on knowledge in action in collaborative teamwork poses several measurement problems (Hmelo-Silver, 2003). As can be deduced from this thesis we only dispose of a few instruments to measure knowledge communication aspects during team collaboration. Available instruments focus rather on knowledge outcomes, counting type and number of objects created than on knowledge processes. The debate on the nature of knowledge flows in teams also reflects the measurement dilemmas. For our study we used existing instruments and developed some instruments to measure, indirectly via participant's perception, the emergence and development of relevant knowledge constructs for the collective outcome.

Practical implications

Our investigations showed that "knowledge" building in professional team performance is highly situated. It is entwined with a particular team, their task and their setting at that stage of discourse. Profitable interventions have to meet all key variables. Based on the insights derived from the literature review and expert consultation we designed two elicitation instruments: the *Ideasticker*, with a single fixed format support for the whole knowledge co-construction process, and the *ACE scenario*, an adaptive stimulation scenario with different elicitation and inquiry prompts combined with and affording modalities per knowledge building phase.

From the research so far the following practical advices can be deduced:

1) Perform a pre-analysis of requirements for optimal elicitation in the specific work practice. Analysis of objectives and constraints of the specific team setting are needed to decide for the optimal support strategy. Based on the experts' comments from the Delphi study and the experimental test it can be concluded that strict elicitation formats as used in initial education and knowledge engineering, are not optimal for a lot of professional work practices. Therefore a prior check is necessary, to explore which type of elicitation support is needed. Prescriptive elicitation methods might prove effective in knowledge engineering elicitation sessions and in requirement analyses for complex or expert system design. Strict formalisms are effective in domains, like in industrial manufacturing and in technical engineering, where people use already highly sophisticated formalisms, which add value (Klein, 2000). For ill-structured, more fluid types of complex problems in professional practice however, prescriptive elicitation methods prove to be too restrictive, too laborious to use and too difficult to learn to provide added value within the team's performance life cycle (Selvin, Buckingham Shum, Sierhuis et al., 2001b). The challenge is to find the optimum of required elicitation support for respective domain- team -problem type combinations. For the problem type addressed in this project, we proposed structured but flexible methods of elicitation. For specific problems in business, information technology and engineering, concerning large systems development elicitation has to prioritize uniform formalism over informal flexibility of generative dialogues. Elicitation then has to prompt and support team members to articulate their contributions according to the modeling formalism, agreed upon in the professional community of that domain or project.

2) Use elicitation scenarios that recognize the dynamics of the work practice. Try to optimize elicitation through options that enable teams to tailor the support to their needs.
Experiments with the two types of elicitation support instruments showed the need for flexible elicitation intervention scenarios. It proves to be important that scenarios are flexible enough to follow the dynamics of a particular setting and can be adapted to their support needs. Feedback from business professionals in de Delphi study and from participants in the experiments indicate that often in itself useful sophisticated single action, single format elicitation methods sort sub-optimal results on complex ill-defined tasks when used in the open setting of virtual teamwork.

3) Use flexible scenarios, capable to follow the whole knowledge co-construction cycle. Select elicitation scenarios, which like the *ACE scenario*, support the further evolution and adaptation of articulated ideas. Prompting team members to contribute not yet articulated ideas requires, as the experiments showed, follow up support once the idea is surfaced. Once articulated, ideas have to first survive and next integrate into the shared knowledge constructs of the team. Support has to take into account that individual insight, once articulated, travels as a "tangible object": a proposal, a discussion contribution, a mind map, or scheme. It transcends from its individual start through multiple transformations during the teams discourse to integration into a team's final knowledge constructs: a report or product.

4) Develop elicitation scenarios in participation with the users. Let users participate in the "co-creation" of optimal elicitation supports (Wierdsma, 1999). Develop elicitation mechanisms for professional workspaces, which users can modify, adapt and enlarge during use, to optimally suit their needs. In the final experiment we offered users with *ACE forum* a combined set of elicitation and inquiry triggers and enabling functions to be used to suit the teams wishes.

5) Offer users options for multiple views on the elicited knowledge under construction. In the *ACE scenario*, users were able to view their knowledge constructs from different perspectives. Results point to positive reception of these functionalities. Analysis of logging and user comments have to provide further insight into the use and precise effects of respective representation formats.

6) Define the aim of elicitation support for the specific work practice. Is solely facilitation of the process or also active augmentation to maximize solution quality required? Ask whether it is worthwhile to embed specific triggers with expert advice, which prompt a team to take their inquiry a step further. In line with research on work based learning (Fischer & Ostwald, 2002) and group decision support (Santanen & De Vreede, 2004) and the results of the final experiment we claim that effective learning while working profits from additional elicitation support, including explicit prompts to stimulate further reflection and deep inquiry for maximization of team result. The *ACE scenario* tested generic expansive inquiry prompts, based on double loop learning and TRIZ based techniques, in combination with domain specific advice.

Implications and further research

This dissertation explored possibilities to augment collaborative knowledge elicitation and trigger expansive inquiry. It generated three complementary contributions.

First, it integrated existing theoretical findings from different disciplines and areas of research. It offered in this way a complementary foundation for elicitation triggering scenarios.

Second, it designed and tested two elicitation support tools aimed at elicitation prompting to enhance relevant individual contributions to team knowledge.

Third, it delivered additional insight on the dynamics of knowledge elicitation processes in distributed collaborative practices. It surfaced further requirements for elicitation support from experts as well as users.

Due to its practice driven motive, this project focused on design over theory building. We applied existing theoretical models, in new combinations and ways. However, in these theoretical models the mechanisms of knowledge building in general and elicitation in specific in computer-mediated teamwork are yet not fully understood and point of debate. Therefore, there are still many theoretical relevant issues to be investigated in this field.
To date engineering pragmatics tend to dominate many areas of professional knowledge development. With the growing importance of distributed team practices, construction of conceptually solid frames of reference are important. Without it, existing problems and successes as well as effects of deliberate interventions are difficult to interpret. The foundations and interpretative strengths of the variety of existing theoretical frameworks to explain knowledge processes in work practice are heavily debated.
As for our subject in particular, further study is needed on the emergence and crystallization of individual knowledge. New theoretical insight into the nature of knowledge emergence in practice is crucial since we need to answer questions as to whether elicitation needs active prompting, or not.

Recently research initiatives from for example Majchrzak (Majchrzak & Malhotra, 2004), Tsoukas (Tsoukas & Chia, 2004), Orlikowski (Orlikowski, 2002; Haythornthwaite et al., 2003), Snowden (Kurz & Snowden, 2003), Engeström (Engeström, 2004) and Handzic (Handzic & Chaimungkalanont, 2004), are relevant to proceed investigations, since these authors try to find new ways to capture the dynamics of team knowledge and its transformations. Further exploration is needed into the conditions influencing the emergence and transformations of team knowledge. Ongoing debates on the nature of knowledge flows in

teams reflect measurement dilemmas related to these issues. How do we assess the emergence of knowledge? Studies in this direction can take advantage of recent knowledge building observations, with the team level as unit of observation. (Cooke et al, 2000; Hmelo-Silver, 2003; Santanen & De Vreede, 2004).
Within the frame of this project two elicitation instruments were developed and tested. The *ACE scenario* has only been straightforwardly tested, in a relatively short laboratory test. Its quantitative results have to be complemented and compared to qualitative results.

Further studies have to reveal the strength of prompting effects over time in real life settings. Do effects observed in the laboratory sustain in daily practice? What exactly causes the effect of elicitation prompts on the knowledge building discourse? How does it effect the emergence of shared understanding and ultimate co-constructed collective solutions?
Directions for future investigations might zoom in into various dimensions: the knowledge outcome, inquiry dimension of the scenario and support for enhancing survival chances of individual contributions to team knowledge. Other questions are whether prompting sorts significant effects on the quality of team performance over time. Research could focus on precise effects of a certain type of inquiry prompts. Agile design methods are needed to compose these inquiry prompts and optimal methods to alert users to them are relevant to investigate. Effects of domain related and generic hints in daily problem solving could be addressed. What types of knowledge are elicited when prompting is used with a certain category of problems? Investigations into the precise relevance of prompted knowledge for the process quality and its outcome is also needed. Does it influence the depth of inquiry? Does elicitation advice enhance the survival chance of relevant contribution?

The subject area dealt with in this thesis lends itself for further investigations in fundamental as well as applied directions. Scientific discourse is needed between researchers and practitioners from various disciplines. Further exploration of epistemological foundations of knowledge elicitation and communication may help to gain new insight and explicitate new frames of reference useable in design and design-based research for ongoing and emergent practices (Cook & Brown, 1999; Engeström, 2004; Kurtz, & Snowden, 2003; Orlikowski, 2002).

To address the complexity of knowledge development of professional teams in real life requires coordinated effort. Progress can be made when a critical problem type or a new elicitation method is investigated in representative practices, from various perspectives, across large populations over longer periods.

Concurrent future research has to investigate optimization of elicitation support formalisms to specific domain or practice characteristics. It is planned for the near future to investigate the effects of the *ACE scenario*, when applied in daily practice of graduates for a semester period of time. This is a setting to test the interventions robustness in real life practice, the optimal mediation format and its effect on benchmarked performance results. Via similar field tests in postgraduate work practices the effects of active knowledge elicitation and communication support can be evaluated and further developed into effective and sustainable support interventions for specific professional practices.
Strategies applied to investigate major problems in medicine and industry might offer advantageous ideas to develop pragmatic design strategies to "engineer" new solutions (Burkhardt, & Schoenfeld, 2003; Burkhardt, 2005; Reeves, 2005).

For effectiveness of future research meta-analyses are needed to develop an overview of the existing state of art in research and practice and identify critical needs and potential gain of elicitation support.
The theory-based design started in this thesis has to be continued with successive actions to engineer valuable elicitation support for knowledge development in professional practices.

Appendix

Appendix 6.1.1 Synopsis of a TRIZ based hint

<table>
<tr>
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<td>
-In pursuit of the best team's proposition-

? Another VIEW - Another HAT?

Investigate whether you are satisfied with the outcome.
Look from another perspective.
Check the implications for the proposal.

!Provoke!

Test the ultimate strength of your proposition.
Worst case test: investigate worst implications.
Go extreme test: consider the most extreme circumstances.
What if test: what happens if you change the constraints.

Enablers: structure fields, meta-tagging, synthesis messages, chat.
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Appendix 6.1.2 Synopsis of a "double- loop" inspired hint

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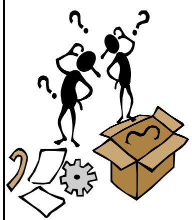
<td></td>
<td>
A second thought.
-Quest for a sustainable solution –

!Think twice!

Who is satisfied?
Does the team solution deliver success for the short run or the long run? Symptoms addressed?
Right problem solved?

!Think different!

Think different, radically different.
What happens if you could change radically?
With use of other dimensions to "reorganize"?

Enablers: structure fields, voting option, meta-tagging, synthesis messages, chat.
</td>
</tr>
</table>

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Summary

Computer based professional teamwork in globally dispersed teams has become more important in industry, research and distance education over the years. For the quality of collective performance effective integration of individual team member's knowledge and learning capacity is decisive, requiring methods for effective knowledge elicitation and communication. This thesis investigates new methods to capture individual knowledge and augment systematic and creative inquiry to expand the horizon of existing insight and explore new grounds. It generates three complementary contributions. First, it integrates existing theoretical findings from different disciplines and areas of research. In this way it offers a complementary foundation for elicitation triggering scenarios. Second, it designs and tests two elicitation support tools, the *Ideasticker* and the *ACE scenario*, aiming at elicitation prompting to enhance relevant individual contributions to team knowledge. Third, it delivers additional insight on the dynamics of knowledge elicitation processes in distributed collaborative practices and surfaces further requirements for elicitation support from experts as well as users.

Chapter 1 presents an introduction into the field of knowledge elicitation support in multidisciplinary teams, reviewing prior research, alternative perspectives and existing theoretical models. As the current study is practice driven, its focus is on designing and testing tools for triggering knowledge elicitation and communication, applying existing theoretical models in new combinations and ways. It is decided to pragmatically define "collaborative knowledge building" as a collaborative situated knowledge construction process. The materialization of individual thoughts, once elicited in tangible representations such as texts, images and figures, is an essential step in this process. Effective support for collaborative knowledge building in virtual teams requires that manipulations on these artifacts adequately cope with the dynamical evolution of ideas as they evolve to collective knowledge constructs.

Chapter 2 reports a Delphi study that was carried out to complement findings from an extensive literature review. The study was set up to elicit expert views on critical factors for stimulation of productive knowledge construction processes in computer-mediated teamwork. Experts insisted on frequent prompts for reflection and suggested shifting from primarily content driven prompting to prompts triggering process and context variables. They offered as specific suggestions to trigger ongoing team commitment and monitor the state of shared understanding and performance progress. Finally they emphasized that only support with a perceived added value for the user will succeed.

Chapter 3 describes how, based on these findings, the prototype of an elicitation-prompting tool, the *Ideasticker*, was developed and tested. This tool combines stimuli for content articulation and triggers to structure process aspects via a simple text-based template, prompting to articulate core concepts, underlying arguments and expected impact on the result. It is assumed that through this additional information the communication of the rationale of the idea is improved. Since in real life multi-disciplinary multi-expertise teams are common and Delphi experts suggest that team characteristics might influence elicitation requirements, special attention is given to the question whether users' expertness necessitates a customized tool format. In contrast to our expectation, results of this study didn’t provide evidence for the assumption that proficiency of the team members is crucial to the mode of elicitation support.

Chapter 4 presents experiences with an improved version of the *Ideasticker*. In this version open fields are used for initial ideas and social talk, in combination with separate fields for presentation of underlying rationale and prospective expectations. Graduate social sciences students at the Open University of the Netherlands team-wise tested the new elicitation support on a complex design task and presented a collective proposal. Via logging and surveys we investigated the use and appreciation of the *Ideasticker*. The test had a within-subject design to be able to observe how the same team experiences a situation with and without active support. Respondents, in general, were positive about this type of elicitation support and its potential. The within-subject test didn't sort statistically significant effects of the treatment on dependent variables like knowledge communication, collaborative openness or trust. Possibly these results were influenced by the short period of use and the fact that the final phase of the course offered unfavorable conditions for the use of the support tool. The qualitative output drew our attention to substantial changes in user's structuration needs over time during collaborative problem solving.

These ideas together with further literature study inspired the design of a new, alternative elicitation support method. This new method recognizes the changing elicitation needs per phase of knowledge co-construction. It brings together ideas from four communities, computer-supported collaborative learning, participatory systems design, organizational inquiry and innovative problem solving. The result is a scenario for augmentation of collaborative elicitation, referred to as the *ACE scenario*. Its focus is on maximal fit of elicitation support to the dynamic evolution of a teams' knowledge co-construction process. This is combined with triggers for expansive inquiry based on Argyris ideas of double loop learning and the TRIZ method for inventive problem solving via systematic questioning and reflection.

Chapter 5 reports a test of this *ACE scenario* in a laboratory setting. The experiment tested how teams of 3 to 4 persons came to a collective business proposal on an authentic management problem. Half of the teams were randomly assigned to a workspace without any support, the others were offered the *ACE* elicitation support. Analysis of quantitative data showed that the treatment sorted predicted improvements as to the participants' own performance ratings, their motivation, perceived quality of team processes and knowledge processes. Expert rates for team performance didn't yet sort significant differences between the two conditions. Quantitative positive perceptions are supported by the qualitative comments of participants.

Finally, *chapter 6* draws up the balance and reviews insights gained, limitations of research, practical implications and directions for further research. Investigations showed that "knowledge" building for professional team performance is highly situated. It is entwined with a particular team, their task and their setting at that stage of discourse. Profitable interventions have to meet all key variables. Practical implications are that in order to enhance effective knowledge articulation and communication for teamwork, a pre-analysis of requirements and a definition of the aim of optimal elicitation for that specific work-practice is necessary. Furthermore, it is important to use flexible elicitation scenarios that recognize the dynamics of the specific work setting at hand and are capable to follow the evolution of the whole knowledge co-construction cycle. User options for multiple views on the elicited knowledge under construction are important, as is the participation of users in the development of elicitation scenarios.

Future research has to investigate optimization of elicitation support formalisms to specific domain or work-practice characteristics. It is planned for the near future to investigate the effects of the *ACE scenario*, when applied to the regular work-practices of graduate students for a semester period of time. This is a setting to test the interventions robustness in real life, the optimal mediation format and its effect on benchmarked performance results. Via similar field tests in real-life postgraduate work-practices the effects of active knowledge elicitation and communication support can be evaluated and further developed into effective and sustainable support interventions for specific professional work-practices. Strategies applied to investigate major problems in medicine and industry might offer advantageous ideas to develop pragmatic design strategies to "engineer" new solutions.

The subject area dealt with in this thesis lends itself for further investigations in fundamental as well as applied directions. Scientific discourse is needed between researchers and practitioners from various disciplines. For the effectiveness of future research we need to identify critical needs and potential gains of elicitation support. The theory-based design started in this thesis has to be continued with successive actions to design valuable elicitation support for knowledge development in professional practices.

Samenvatting

Het oplossen van complexe vraagstukken gebeurt steeds vaker door experts die in multidisciplinaire teams virtueel, veelal langs elektronische weg, samenwerken zonder elkaar rechtstreeks te ontmoeten. Voor het uiteindelijke teamresultaat blijkt het van groot belang dat tijdens het oplossingsproces relevante kennis van individuele teamleden expliciet ingebracht en daadwerkelijk gedeeld wordt. Het is bekend, dat in situaties waarin teamleden elkaar niet rechtstreeks ontmoeten deze kennisontwikkeling problematisch kan verlopen. Het onderzoek in dit proefschrift richt zich op de vraag hoe in dergelijke situaties de kennisontwikkeling optimaal te stimuleren en te faciliteren is. Het gaat daarbij met name om het expliciet kenbaar maken (eliciteren) van relevante kennis van individuele teamleden, het integreren ervan in het gezamenlijk inzicht over het probleem en het op basis daarvan gemeenschappelijk verkennen van nieuwe oplossingsrichtingen.
Het beschreven onderzoek tracht bijdragen te leveren in drie richtingen. Allereerst zijn bestaande theoretische inzichten uit verschillende vak- en onderzoeksgebieden rond kennisontwikkeling samengebracht en geïntegreerd in een nieuw kader voor het ontwikkelen van scenario's om kenniselicitatie te stimuleren. Daarnaast is een tweetal concrete instrumenten om kenniselicitatie te ondersteunen ontwikkeld en getest, namelijk de *Ideesticker* en het *ACE scenario*. Tenslotte zijn, op basis van meningen van experts en ervaringen van gebruikers, nieuwe inzichten verworven in de dynamiek van kennisarticulatie en communicatie processen bij computer gemedieerd teamwork.

Hoofdstuk 1 introduceert de thematiek van kenniselicitatie in multidisciplinaire teams en geeft, op basis van een literatuuronderzoek, een overzicht van eerder onderzoek en bestaande theorieën op dit gebied. Op basis hiervan is een kader geformuleerd voor het ontwerpen en testen van praktische gereedschappen om gezamenlijke kennis binnen virtueel samenwerkende teams te ontwikkelen. De gekozen invalshoek is die van een gesitueerd gezamenlijk constructieproces,

waarbij de kennisontwikkeling plaatsvindt vanuit een specifieke situatie en gericht is op een specifiek gemeenschappelijk doel. In dit proces is het van belang impliciete kennis van individuele teamleden door middel van concrete representaties zoals teksten, figuren, schema's of tekeningen in kaart te brengen, aan de hand waarvan de verdere dialoog plaats kan vinden. Om de verdere kennisontwikkeling tussen de leden van het team te ondersteunen, is het zaak dat de materiële representaties waarin de geuite ideeën neergeslagen zijn, kunnen meegroeien met de dynamiek van de zich ontwikkelende collectieve ideeën rond probleem en probleemoplossing.

Hoofdstuk 2 beschrijft een Delphi studie die uitgevoerd is als aanvulling op het literatuuronderzoek. Doel ervan is om inzicht te krijgen in de visie van experts met betrekking tot de kritische factoren voor het stimuleren van kennisontwikkeling binnen virtueel samenwerkende teams. Experts benadrukten dat het belangrijk is om frequent en doelgericht op te roepen tot gezamenlijke reflectie. Ondersteuning dient zich niet te beperken tot de inhoud maar moet zich ook richten op relevante proces en context aspecten. Meer specifiek gaven de experts aan dat het belangrijk is om alle leden bij het team betrokken te houden en om de ontwikkeling van de gemeenschappelijke kennis en de vooruitgang met betrekking tot het teamdoel voortdurend te blijven volgen. Kritisch voor de acceptatie en het effect van de te ontwikkelen ondersteuning is dat gebruikers de directe toegevoegde waarde ervan ervaren.

Hoofdstuk 3 beschrijft hoe, gebaseerd op de inzichten uit het literatuuronderzoek en de Delphi studie, een eerste instrument voor ondersteuning van kenniselicitatie ontwikkeld en getest is, de *Ideesticker*. Ze stimuleert tot het gestructureerd en helder uitspreken van niet enkel de inhoudelijke aspecten maar ook van de bijbehorende beweegredenen, onderbouwing en het verwachte effect met betrekking tot de uiteindelijke oplossing. De veronderstelling is dat op basis van deze toegevoegde informatie individuele bijdragen beter te interpreteren zijn. Omdat onder meer in het Delphi onderzoek de suggestie naar voren kwam dat een verschil in expertiseniveau een verschil in ondersteuningsvoorkeuren en behoeftes in kan houden is hier bij het testen van de eerste versie van de *Ideesticker* aandacht aan besteed. Dit leverde echter geen duidelijke aanwijzingen op voor de noodzaak van een gedifferentieerde ondersteuning naar expertise achtergrond van de gebruiker.

Hoofdstuk 4 presenteert de ervaringen met een verbeterde versie van de *Ideesticker*. In deze versie zijn open velden toegevoegd voor een associatieve omschrijving van het idee en voor sociale conversatie alsmede aparte structuurvelden voor het presenteren van de onderliggende rationale en verwachtingen ten aanzien van het ingebrachte voorstel. Studenten sociale wetenschappen aan de Open Universiteit Nederland hebben deze aangepaste versie van elicitatie ondersteuning beproefd bij het in teams oplossen van een complexe ontwerptaak. Effecten en waardering van deze nieuwe versie van de *Ideesticker* zijn bestudeerd op basis van de gelogde activiteiten en ingevulde vragenlijsten. Daarbij is gekozen voor een experimentopzet waarbij teams alleen tijdens de tweede helft van het teamwerk door middel van de *Ideesticker* ondersteund worden, dit om per team verschillen in aanpak met en zonder ondersteuning te kunnen identificeren. Deelnemers bleken in het algemeen positief over de feitelijk ondersteuning door de *Ideesticker* en over de verdere mogelijkheden ervan. Effecten op afhankelijke variabelen zoals de mate van kenniscommunicatie en de openheid van het samenwerkingsproces bleken echter niet significant aantoonbaar. Mogelijk dat de korte periode van gebruik en het feit dat in de eindfase van het project door groepsproblemen ongunstige omstandigheden voor het gebruik van de elicitatie ondersteuning ontstonden hierbij een rol spelen. Uit commentaren van gebruikers bleek dat de structureringsbehoefte per probleemoplossingsfase substantieel verschilt.

Op basis van deze bevindingen en aanvullend literatuuronderzoek is vervolgens een nieuwe vorm van elicitatie-ondersteuning ontwikkeld, waarin rekening gehouden wordt met de veranderende structureringsbehoeften in de verschillende probleemfasen. Ideeën uit vier verschillende gebieden zijn daartoe samengebracht, namelijk de gebieden van computer gebaseerde samenwerken en samen leren, het participatief ontwerpen, organisatorische kennisontwikkeling en creatief probleem oplossen. Resultaat is het zogeheten *ACE scenario*, een scenario dat beoogt om de elicitatie-ondersteuning optimaal aan te laten sluiten bij de dynamische evolutie van het proces van gezamenlijke kennisontwikkeling. Ideeën gebaseerd op Argyris' double loop learning voor het systematisch verbreden van het oplossingsperspectief en op de TRIZ-methode voor creatief probleem oplossen door middel van systematische vraagstelling en reflectie zijn daarin geïntegreerd.

Hoofdstuk 5 beschrijft een laboratorium experiment met dit *ACE scenario*. In dit experiment is onderzocht hoe teams van 3 à 4 personen een gezamenlijke oplossing voor een realistisch managementprobleem ontwikkelden. Daarbij is gekozen voor een experimentopzet waarbij de helft van de teams geen verdere ondersteuning kreeg, terwijl de andere helft van de teams de beschikking had over het *ACE scenario*. Uit analyse van de kwantitatieve data blijkt dat de voorspelde verbeteringen met betrekking tot de door het team ervaren kennis- en samenwerkingsprocessen en de ervaren kwaliteit van prestatie en motivatie door gebruik van het *ACE scenario* daadwerkelijk optraden. Kwalitatieve open opmerkingen van gebruikers stroken met deze conclusies. Onafhankelijke beoordeling van de teamprestatie door experts liet echter geen significant verschil zien tussen groepen met en zonder *ACE scenario*.

Hoofdstuk 6 tenslotte maakt de balans op van het uitgevoerde onderzoek en vat de verworven inzichten, onderzoeksbeperkingen, praktische implicaties en richtingen voor toekomstig onderzoek samen. Geconcludeerd wordt dat kennisontwikkeling binnen professionele teams een gesitueerd constructieproces is, dat direct vervlochten is met het specifieke team in de betreffende oplossingsfase. Succesvolle interventies dienen bij deze aspecten aan te sluiten. Een praktische implicatie uit het onderzoek is dat voor het optimaal stimuleren en faciliteren van kennisontwikkeling een analyse vooraf van doelstelling en eisen voor optimale elicitatie binnen de aangegeven situatie noodzakelijk is. Bovendien is het belangrijk om de gebruikers al vroeg bij het ontwikkelen van de scenario's te betrekken. Flexibele elicitatie scenario's, die aansluiten bij de dynamische evolutie van het proces van gezamenlijke kennisontwikkeling, zullen het meest effectief zijn. Tenslotte zijn mogelijkheden om de tijdens het proces verworven gemeenschappelijke kennis op meerdere manieren te representeren noodzakelijk.

Verder onderzoek kan zowel fundamenteel-theoretisch als toegepast zijn. Enerzijds is het zinvol om te identificeren waar, op basis van de actuele theoretische stand van zaken, de kritieke noden liggen en waar potentiële winst te halen is met elicitatie ondersteuning. Anderzijds zou toekomstig onderzoek zich kunnen richten op de optimale aanpassing van kennis-elicitatie en kennis-communicatie instrumenten aan specifieke domeinen en de toepassing ervan in de beroepspraktijk. Voor de nabije toekomst staat onderzoek naar de effectiviteit van het *ACE scenario* bij regulier gebruik door studenten gedurende een heel semester gepland. Doel is om in representatieve situaties de robuustheid, inpassing en effecten van het *ACE scenario* tijdens het gebruik in de dagelijkse praktijk te onderzoeken. Resultaten kunnen leiden tot het doorontwikkelen van de huidige scenario’s en tot nieuwe, effectieve en “duurzame” interventies, aangepast aan specifieke beroepssituaties voor bijvoorbeeld de medische en industriële wereld. Op een dergelijke wijze kan het theoretisch gebaseerde onderzoek dat gestart is in deze dissertatie, gecontinueerd worden in opeenvolgende ontwikkelacti-viteiten om waardevolle kennisondersteuning voor de professionele praktijk te ontwikkelen.

Curriculum Vitae

Marlies Bitter-Rijpkema studied history and geography in Tilburg and graduated in contemporary history from Nijmegen University (KUN, 1980). She taught history and social sciences in secondary education (1976-1982) and at the KLS, Institute of Higher Education. Here she extended her activities to the teaching of informatics and the design of new ICT opportunities into education (1982-1986).
Between 1986 and1988 she was project manager for the humanities domain in the ICT stimulation program NIVO of the Ministry of Education and founder of COMIGO, the IT in History Education teacher community. To enhance students' cultural interests she organized multiple tours across Europe, Africa and Asia (1984-1992).
Since 1986 she works at the Dutch Open University (OUNL) as educational technologist and assistant professor (UD). Here she specialized in the design of interactive applications for distance education in various domains, such as business sciences, cultural sciences, law, informatics and mathematics. She also acts as an educational consultant for e-learning via advanced technologies.
Her actual research interests focuses on work-based learning, knowledge development in collaborative settings, virtual business, group decision support and performance assessment. Furthermore, she is liaison officer at the Open University for the “Digital University” consortium.

The illustration on the cover symbolizes the circle of knowledge created by sharing individual's expertises.